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An Alternative Approach to a Helicopter Voice Advisory Information System

Prepared for Transportation Development Centre

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Un sommaire en français de ce document est inclus avant la table des matières.

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17. Abstract

This study describes the development of the hardware for a helicopter voice advisory information system (VADIS) and the software to adapt the system to the Bell 206 Jet Ranger. Detailed analysis of hardware and software design and construction is provided, as well as a sample software program listing for the target helicopter. Design trade-offs and decisions are covered with regard to current and future applications. The report concludes with an outline of projected development and marketing for the VADIS system and the legal approval issues affecting its use in Canada.

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17. Résumé

Cette étude rend compte de la mise au point d'un système embarqué d'avertissement/alerte par messages vocaux (VADIS) pour hélicoptère et du logiciel permettant d'adapter ce système à l'hélicoptère Bell 206 Jet Ranger. Une description détaillée du matériel et du logiciel est donnée de même qu'un échantillon représentatif du logiciel utilisé pour cet hélicoptère. Les décisions et choix techniques à faire sont expliqués en fonction des réalisations tant actuelles que futures. Enfin, les perspectives de développement et de commercialisation du système sont évoquées, ainsi que les barrières administratives et juridiques qui restent à abattre au Canada.

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Summary:

This project has addressed the task of producing a 'flyable' version of the HSA-70 aircraft voice advisory or VADIS system. This is a device which translates critical flight conditions in the aircraft into spoken advisory information delivered immediately to the pilot. The original concepts developed by Northern Airborne Technology Ltd. (covered in "Development of a Prototype of a Helicopter Voice Advisory System: VADIS", for Transportation Development Centre, TP5461E, May 1984, and briefly revieved here) have been taken to the flight ready stage during this phase, exhaustively tested, and represent a sophisticated design platform that can be used to test and evaluate all aspects of the VADIS concept in the future.

To understand the purpose of such a system, and the typical aircraft environment in which it works, a short general overview is included here. This is followed by a technical review of the HSA-70 hardware and software developed during this project, and a plan of future activities. Readers are strongly urged to consult the above-referenced document for a more exhaustive treatment of VADIS system motivation, and the background information on flight related factors.

VADIS OVERVIEW:

Over the years, many methods have been used to improve the transfer of information from machines to human beings. Aircraft present a particularly difficult setting for this problem because of the large number of systems they contain, the situational stress levels, and because of the extreme importance and time pressure of the information they present.

A wide variety of visual cues have been developed for pilots in terms of indicators, warning lights and placards, but these methods always assume that someone will chance to look at the right indicator at the right moment. To improve the chances of informing the pilot in critical situations, simple audio cues have been added, such as horns, sirens, and buzzers. The combination of these methods is expected to attract the pilot's attention in a timely fashion, and avert serious airframe damage.

Unfortunately, there are many more fault situations than there are easily generated sounds, and not everyone remembers exactly what a certain sound represents in moments of stress. In addition, time is always wasted during the associative process of matching sounds and lights to instruments, then instruments to systems, and finally systems to corrective actions. It is to this operational problem that the VADIS system is targeted. It delivers a concise spoken message which clearly identifies the level of danger and the system involved.

When current generation helicopters were designed, technology was not able to support voice messages, and simple devices such as sonalerts or horns were used for annunciation. With the advent of the microprocessor and sophisticated voice synthesis techniques, however, this previous barrier can be overcome. The HSA-70 uses the latest microprocessor LSI and memory techniques to provide this function as well as full flight data storage, all in a container roughly the size of a shoebox.

Since the work profile of a helicopter is much different than that of a fixed-wing aircraft and often requires the attention of the pilot outside the cockpit, helicopters present the most useful application of the HSA-70. In addition, most helicopter dynamic components and power-train components are of limited life and often have replacement associated with maximum stresses. This increases the need for better control by the pilot, and has significant economic implications for the owner/operator, if component life can be increased, or at least fully utilized.

A system that can improve the information transfer to the pilot has a two-fold implication then, one of safety, and one of cost control. History has demonstrated that people often take little notice of their safety, so it is a significant benefit that this system has positive economic side-effects. Use of the system will prove attractive for those economic aspects, and the significant safety improvement will have its chance.

HSA-70 DEVELOPMENT PLATFORM

The system developed under this project is an interlocking system of three microprocessors, each handling a specific task within the HSA-70. A 'supervisory' or main CPU handles the raw data acquisition from the aircraft and performs the comparison with stored fault profiles for the specific aircraft. A remote control head processor handles all the pilot interface and display driving functions. A final Linear Predictive Coding or 'LPC' processor handles the complex task of generating the actual speech output of the computer system.

LPC is a specific technique for processing digitized speech that conserves memory requirements by being able to mathematically forecast or "predict" how a word will sound based on speech rules applied to a partial sample of the desired word. This makes large vocabularies with small memories practical, and still retains natural sounding speech. This technique is ideal for the VADIS system, and was used to make the final product practical and economical. The actual words used are made from true human speech, which has been digitized by a reverse process and then stored in digital memory.

The division of labour in the system allows time critical functions to proceed without hardware interference caused by parallel processes. Actual program control of the microprocessors is achieved by an in-house language called RASOR (main CPU) and assembly language coding (control head). The LPC processor is self-controlling through internal micro-code, and requires only simple speech commands from the main CPU.

RASOR provides an important bridge between the computer operation and human programmers, in that it allows machine level control with high-level syntax. This greatly speeds coding and porting of the code to new airframes, and analysis and correction of existing programs. Assembly coding is used in the control head only because of the extreme simplicity of the control head operation, and its low requirement for change.

The computer can analyze two sources of input data from the aircraft, analog variable value data and two state digital data. This information is taken 'parasitically' from existing systems in the aircraft, without disturbing their normal function. Only one additional sensor system has been required by the HSA-70 (on the Bell 206 Jet Ranger helicopter), which is a pressure sensor used to tap hydraulic indication of engine torque. All other data was found to exist in suitable form, after post processing in the HSA-70.

A great deal of data is already in digital (or on/off) format in the aircraft, in order to drive caution lights and horns. These signals were not directly compatible with the digital logic in the computer, so additional conditioning and isolated coupling was required for these inputs, and is provided by the digital interface card in the HSA-70. A total of 32 digital inputs are supported, one of which is reserved for a 400 Hz power monitor, one for an anti-tamper interlock, and one for a navigation super-flag warning. The others are 'ground-seeking' logic inputs, arranged in groups of varying priority. A visual annunciation is provided on this interface to aid in troubleshooting each input during installation.

Analog data is much more complex, and is handled in groups of eight channels on each analog interface card. Three tach generators (RPM indicators), a thermocouple, an absolute temperature indicator, and three variable DC level measuring circuits are supported on each card. All of these measurements are made either through optical isolators or 'isolation' amplifiers, to prevent any possible ground loop interference or system interaction with existing equipment. Up to two such cards can be used in each computer, to handle twin-engine aircraft applications.

The main microprocessor (and its support circuits contained on the main CPU card) takes care of checking and converting the input data. It also controls the comparison process that is used to determine if the data received represents a situation where the pilot must be advised. These "profiles" of the aircraft are stored in EPROM memory, along with the control program, and are constantly in play as the computer receives data from the airframe. When a decision is reached that requires pilot advisory, the speech processor is activated and the required message is sent to the pilot through an audio interface circuit into his headset.

Since the main processor is fairly busy examining the aircraft information during flight, it would be difficult for the same processor to also control the generation of speech, except in a cursory way. The LPC processor takes over from this point and operates on its own, allowing the monitoring of the aircraft to proceed during speech. It controls its own memory (which stores words and phrases), and is a self-contained microprocessor system, requiring only a simple code from the main computer indicating the word(s), tones or silences that must be output. This function is completely contained on the synthesizer card.

Message structure is critical to insure that the pilot's attention has been caught, and that he correctly understands the fault being described. All messages follow the same syntax, and are keyed to simple levels of importance: CAUTION, WARNING and DANGER, which clarifies the situation to the pilot. Messages are also presented on an exception-only basis, which means that the computer is not constantly nagging the pilot with a running commentary on life in the helicopter.

The message to the pilot must be brief, but clear and unambiguous. In addition, priority logic has to insure that the pilot always receives the most important message first, and without delay. These formatting functions are taken care of in the software used by the main processor, which sets up the speech commands for the LPC processor. The profile program which controls all of these decisions is written in RASOR.

In addition to delivering the fault message, the computer also performs several other functions which are just as significant. First, if the message reflects a serious condition in the airframe requiring inspection or replacement, a visual flag is permanently set on the control head, to advise both the pilot and engineering staff. Next, the data relating to the event (system, time, duration, values) can be stored in non-volatile memory for recall by anyone, and played back through the ship's audio system. Finally, a complete automated record of airframe performance and operation can be off-loaded to another computer for record-keeping and analysis.

This storage is accomplished by use of two relatively new types of solid state memory, NOVRAMS (non-volatile random access memory) and EEROMS (electrically erasable read only memory). The NOVRAMS allow continuous write operations, and are used for running times, counters, events, cycles, etc., and are written and stored at the power-down cycle of the computer. The EEROMS represent a very large storage area (at least 48K by 8 bits) and are the archive storage for fault data as it occurs in flight.

Control of this memory is complex, and is discussed in depth in the later sections of this report. It does provide very powerful analytical capabilities for support staff concerning the true state of the aircraft, and is on a par with flight data recorder systems of significantly higher cost. A small portable computer can communicate with the HSA-70, offload the entire history via the serial data port provided, and use it for later analysis. This capability was developed during this phase, from initial theoretical concepts.

The HSA-70 addresses a wide range of problems by these techniques. It provides immediate warning to the pilot of serious or about-to-be serious aircraft situations. It stores the event to ensure correct action is taken, based on known values and times. And it provides continuity of record-keeping to ensure that a full and detailed picture of the aircraft is always available, and not dependent on the vagaries of manual records. In short, it fills in many gaps which exist in current systems and practices.

Since many helicopter components are designed for narrow ranges of stress and may have throw-away limits with times measured in seconds or minutes, this data is of tremendous importance in ensuring that the correct procedure is followed to return the aircraft to service. It also circumvents the problem of unintentional or unknown damage done when the pilot is unaware of the actual stress on the aircraft. The over-all impact of this system is seen as very beneficial to all parties associated with the operation and support of the aircraft.

Cost of final production systems is seen in three parts; a one-shot software and profile/installation interconnect charge, cost of the HSA-70 hardware, and the cost of actual airframe installation. The hardware itself is inexpensive, and can be marketed for between C$5,000 and C$10,000, depending on exact aircraft configuration (single or twin engine, and memory capability).

This is a very low cost relative to anticipated financial benefits, and is expected to prove attractive in the current marketplace. Flight data recorders would be approximately five

times this cost and provide no immediate data advisory. Numerous other approaches have surfaced in the aviation marketplace over the last three years, each with some aspect of the VADIS technique. The HSA-70 remains the only system currently marketed or proposed that covers all aspects of the VADIS concept at an affordable price.

FUTURE DEVELOPMENT

Interest in this system has been expressed by both government and civil operators, and flight testing is scheduled for the latter part of 1987 once some procedural and legal barriers have been overcome.

Of particular concern has been the position adopted by Northern Airborne Technology's insurers, who have specifically declined to extend product liability insurance to cover the use of this system. Despite a year of intense negotiating, this has not been satisfactorily resolved. Flight testing will therefore have to proceed only when a full waiver can be obtained from the operator. The position of insurers on this matter is very difficult to understand, as the system clearly reduces risk in the airframe.

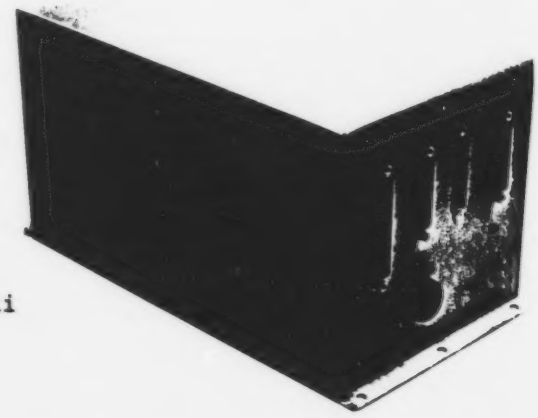
A second issue is the co-operation of Transport Canada in obtaining a suitable flight permit to allow testing, and eventual product approval. This situation is still under consideration, especially with regard to eventual manufacturing approval, but will hopefully be resolved without the need to first obtain US approval, and then re-apply in Canada.

Negotiations are underway with two helicopter operators and the Canadian Coast Guard to perform live flight testing in a variety of airframes. This is expected to lead to some further refinement in the eventual production systems. Extensive lab simulations have already been performed in-house, and three full systems built to prove the hardware and software concepts. These are expected to be used in upcoming flight trials.

Equipment Views:

HSA-70 Computer

Cockpit Control Head



SOMMAIRE

Ce rapport concerne les travaux visant à obtenir une version embarcable du système d'avertissement/alerte par messages vocaux (VADIS) piloté par ordinateur HSA-70. Il s'agit d'un appareil qui lance des messages vocaux d'avertissement dès que des conditions de vol critiques sont détectées. Le concept original étudié par la Northern Airborne Technology Ltd. (voir le rapport du CDT n° TP 5461E), et dont un bref aperçu est donné ici, a été amené au stade des essais de vol et méticuleusement éprouvé, débouchant sur un système de base sophistiqué qui peut servir à une évaluation approfondie du système au complet.

Afin de remémorer l'objectif fixé à ce système et le contexte dans lequel il doit évoluer , un bref rapport historique est donné, suivi d'une appréciation technique du matériel HSA-70 et du logiciel correspondant ainsi que des perspectives d'avenir qui s'ouvrent.

Rappel Historique

Au cours des années, diverses méthodes ont été utilisées en vue d'améliorer le dialogue homme-machines. Dans le cas des avions, le transfert d'information est particulièrement difficile, à cause du grand nombre de systèmes en jeu, des niveaux élevés de stress et du caractère souvent critique de l'information transmise.

Pour alerter le pilote, divers dispositifs ont été mis en place (indicateurs, cadrans, voyants, écran d'affichage), mais tous pèchent par l'obligation d'observer le bon dispositif au bon moment. Afin de mieux attirer l'attention du pilote, des signaux sonores ont été ajoutés: klaxons, sirènes, ronfleurs, etc., dans l'espoir que l'avertissement sera perçu à temps, de manière à prévenir des avaries graves.

Malheureusement, il existe en pilotage plus de situations difficiles que de signaux sonores faciles à produire et, en situation de danger, se rappellera-t-on toujours de ce qu'un signal sonore donné est supposé signifier? Qui plus est, il y a le laps de temps entre le moment où l'avertissement sonore est donné et celui où le pilote réagit; il faut en effet que ce dernier ait d'abord associé le signal sonore à l'indicateur correspondant, puis l'indicateur au système fautif et enfin celui-ci à l'action appropriée. C'est justement cet aspect des choses que le système VADIS cherche à améliorer par les messages qu'il délivre, brefs mais précis.

Lorsque les hélicoptères de la génération actuelle étaient encore à l'étude, la technologie des messages vocaux d'alerte et de mise en garde était inconnue; l'alarme était donc donnée par divers dispositifs sonores. Toutefois, grâce au microprocesseur et aux techniques modernes de synthèse de la parole, les progrès accomplis dans ce domaine ont été

considérables. Les techniques d'intégration grande échelle et la plus grande capacité de mémoire dont a été doté le HSA-70 lui confèrent, outre cette aptitude, celle de stocker toutes les données de vol, avec un encombrement guère plus grand qu'une boîte à chaussures.

Les tâches que doit accomplir un hélicoptère sont très différentes de celles d'un aéronef à voilure fixe, et le pilote d'un appareil à voilure tournante doit très souvent se concentrer sur ce qui se passe au dehors. Dans ce cas, l'utilité des messages vocaux devient manifeste; d'autant que les organes moteurs de l'hélicoptère, notamment ceux de la chaîne cinématique, souffrent d'une durée de vie très limitée, à cause justement des efforts très élevés et souvent de niveau critique qui les sollicitent. Un système d'avertissement par messages vocaux vise à permettre au pilote de mieux maîtriser son appareil et aux propriétaires/exploitants de réaliser d'importantes économies en prolongeant la vie utile des pièces et organes ou, du moins en les utilisant au maximum de cette vie.

Double avantage donc d'un tel système: d'abord sur le plan de la sécurité et ensuite sur celui du contrôle des coûts. L'expérience montrant que les gens se préoccupent peu de leur sécurité personnelle, il est fort heureux que ce système procure également des avantages économiques réels. Ceux-ci emporteront la décision du client potentiel qui bénéficiera, en outre, d'une sécurité accrue.

Développement du HSA-70

Le système étudié comporte trois microprocesseurs interreliés, chacun s'acquittant d'une tâche particulière. Le premier, unité centrale de traitement ou "superviseur", fait l'acquisition des données brutes et les compare aux valeurs de défaut mises en mémoire à l'égard de l'aéronef considéré. Le deuxième, télécommandé, agit comme interface entre l'homme et la machine et règle toutes les fonctions de visualisation. Enfin, le troisième, est un processeur de phonation qui prend en charge la tâche complexe de produire les messages vocaux.

La synthèse par prédiction linéaire permet, avec un encombrement en mémoire réduit, de prédire pour le mot considéré la valeur des signaux de parole à produire, en fonction des valeurs prises par le signal à des instants d'échantillonnage précédents. Elle autorise la formation de grands vocabulaires sans surcharger la mémoire du système et s'approche le plus du naturel intonatif. C'est cet ensemble de qualités qui était recherché pour le système VADIS et qui a mené à un produit final pratique et économique. Quant aux mots retenus, ils reproduisent la parole humaine qui a été numérisée selon un procédé inverse puis stockée dans la mémoire de l'ordinateur.

Grâce à la répartition des tâches, toutes les fonctions critiques peuvent s'accomplir sans être gênées par des fonctions parallèles du système. La commande de tout le programme est réalisée par un langage maison appelé RASOR (unité centrale) et par un langage d'assemblage codé

(tête de commande). Quant au processeur de phonation, il est autonome car il est piloté par une microprogrammation interne et ne nécessite que des commandes simples de la part de l'unité centrale.

RASOR est un langage haut niveau permettant aux programmateurs de dialoguer avec la machine. Il facilite le codage et autorise la transportabilité du logiciel ainsi que l'analyse et la correction des programmes existants. Le langage d'assemblage convient à la tête de commande en raison de l'extrême simplicité de celle-ci et du fait que ce langage n'est pas astreint à une évolution rapide.

L'ordinateur a la capacité d'analyser deux sources de données concernant l'aéronef: des données analogiques variables dans le temps et des données numériques deux niveaux. Ces données sont prélevées sans gêner le fonctionnement normal des organes auscultés. Un seul capteur supplémentaire a été jugé nécessaire sur le Bell 206 JetRanger, un détecteur de pression pour connaître la valeur du signal hydraulique indicatif du couple moteur. Toutes les autres données sont exploitables, sous leur forme actuelle, une fois traitées par le HSA-70.

Une forte proportion des signaux commandant les divers avertisseurs lumineux et sonores des appareils sont déjà sous forme numérique; toutefois, ils ne sont pas directement compatibles avec la logique de l'ordinateur, numérique elle aussi. Il a donc fallu prévoir un traitement supplémentaire pour les signaux d'entrée ainsi que l'isolement du coupleur, assurés par la carte d'interface numérique du HSA-70. Le nombre d'entrées numériques que l'ordinateur peut prendre en charge est de 32 en tout, dont une pour le contrôleur d'alimentation 400 Hz, une pour le verrouillage anti-fraude et une pour le positionnement d'un drapeau en cas d'information fautive sur la navigation. Toutes les autres sont des entrées logiques relatives à la distance sol, réunies en groupes classés selon leur ordre de priorité. Enfin, la carte interface comporte un signal visuel servant à détecter les erreurs de connexion lors de l'installation du système.

L'analyse des données analogiques, plus complexes, est prise en charge par une ou deux cartes interface analogique comportant chacune huit circuits: trois pour les indicateurs du régime moteur (tours/minute), un pour le thermocouple, un pour l'indicateur de température maximum et trois pour mesurer trois niveaux de tension du courant continu. Afin de prévenir une mise à la masse par inadvertance ou toute influence parasite, la télémesure est transmise à travers un coupleur optoélectrique ou un transformateur d'isolement. L'utilisation de deux de ces cartes est prévue dans le cas d'un bimoteur à voilure tournante.

Le microprocesseur principal (et l'ensemble des circuits gravés sur la carte principale de l'unité centrale) vérifie les signaux d'entrée du système et les convertit; il contrôle également le processus de comparaison qui sert à déterminer à tout moment si l'état de l'appareil justifie d'alerter le pilote. Il le fait en comparant les paramètres à des "profils d'état" mis dans une mémoire morte effaçable et programmable

et en se référant, tout au long du vol, au programme de gestion, également en mémoire. Lorsqu'une situation nécessitant la mise en garde du pilote survient, le processeur de phonation est actionné et le message vocal est émis par l'intermédiaire d'un circuit audio.

Etant donné que le processeur principal exécute la tâche de vérifier les données sur l'état de l'appareil en vol, lui confier la production des messages vocaux serait une tâche supplémentaire à laquelle il ne pourrait satisfaire qu'accessoirement. On préfère donc confier cette tâche au processeur de phonation, élément autonome doté d'une mémoire propre formée de mots, phrases, intonations et silences qui sont émis dans un ordre déterminé, sur réception d'un code simple venu du processeur principal. Cette fonction tient sur la seule carte de l'appareil phonatoire.

La structure du message est un facteur d'importance dans le double but d'attirer l'attention du pilote et de bien lui indiquer la nature du défaut objet de l'avertissement. La syntaxe est toujours la même et les messages obéissent à une hiérarchie simple mais claire: CAUTION (Attention), WARNING (Avertissement) et DANGER (Danger). De même, les avertissements ne sont donnés que s'il y a un dépassement, le pilote n'ayant pas à être soumis à un barrage incessant de messages.

Les messages adressés au pilote doivent être brefs, clairs et sans ambiguité. Ils doivent également être hiérarchisés et transmis d'après un ordre de priorité correspondant à l'urgence du message à transmettre. Ces fonctions de mise en forme sont confiées au logiciel du processeur principal qui, au moment voulu, actionne le processeur de phonation. Le programme de gestion correspondant est écrit en langage RASOR.

Le système ne fait pas que livrer des messages vocaux, il exécute aussi de nombreuses autres tâches, tout aussi importantes, soit: positionner un drapeau sur la tête de commande lorsque le message vocal émis correspond à une situation nécessitant la visite ou le remplacement d'un élément de la cellule, attirant ainsi l'attention du pilote et du personnel technique; enregistrer de manière permanente les données relatives à cet événement (système, durée, heure, valeurs) qui peuvent ainsi être rappelées et relues à l'aide du système audio; enfin, tenir le dossier complet relatif à la tenue de la cellule dans le temps, lequel pourra être transféré à un autre ordinateur aux fins d'archivage et d'analyse.

Pour le stockage des données, on se sert de deux mémoires d'invention récente: la mémoire vive non volatile (NOVRAMS) et la mémoire morte effaçable électriquement (EEROMS). La première, qui permet l'écriture continue, sert à graver les temps de marche, l'indication des compteurs, les événements, les cycles, etc. durant le cycle de débranchement de l'ordinateur. La seconde, qui offre au moins 48k d'espace de mémoire 8 bits, sert à archiver les données sur les défauts au fur et à mesure qu'ils se produisent durant un vol.

La gestion de tant de mémoire est ardue. Il en sera question plus loin dans le rapport. Elle apporte néanmoins une puissance d'analyse de l'état réel de l'aéronef utile au personnel de maintenance et égale à celles des systèmes enregistreurs de paramètres qui coûtent beaucoup plus cher. Un petit ordinateur portatif, relié au HAS-70 par une connexion série à travers le port d'entrée-sortie, peut recevoir toute l'information stockée et la soumettre ultérieurement à une analyse approfondie.

Toutes ces techniques permettent au HSA-70 de prendre en charge une vaste gamme de tâches: avertir le pilote des situations dangereuses ou potentiellement dangereuses; enregistrer l'événement pour que l'action appropriée soit prise en fonction de paramètres connus; assurer l'archivage permanent et précis des conditions de service; dresser un tableau complet de l'état de la cellule qui ne soit plus tributaire des enregistrements manuels si imprécis. Bref, il vient combler la plupart des lacunes dont souffrent les systèmes et les procédures actuels.

Etant donné que nombre des éléments d'un hélicoptère sont conçus pour ne supporter des sollicitations hors limites que pendant un temps très court, mesuré en minutes, voire en secondes, les données ainsi recueillies par le système sont vitales car elles présideront au choix de l'entretien à effectuer après coup. Le système joue aussi un rôle de prévention en avertissant le pilote lorsque celui-ci ne se rend pas compte de l'importance des contraintes qui s'exercent sur la cellule. On s'aperçoit donc à quel point un tel système peut être utile à tous ceux qui participent à l'exploitation et à la maintenance des appareils ainsi équipés.

Quant au coût du système en production série, il comporte les trois éléments suivants: un coût unique d'élaboration, d'installation et d'interconnexion du logiciel; le coût du matériel HSA-70 et le coût de l'installation proprement dite. Quant au coût du matériel, il est peu élevé.

Quoi qu'il en soit, ce coût total est très bas par rapport aux avantages escomptés, et cela ne manquera pas d'allécher le marché actuel. Les enregistreurs des paramètres de vol coûtent quelque cinq fois ce prix et ne lancent aucune sorte d'avertissement. Depuis trois ans, divers autres systèmes font leur apparition, proposant telle ou telle caractéristique du système VADIS décrit. Seul, le HSA-70 offre toutes les caractéristiques à la fois, tout en demeurant à un prix largement compétitif.

Perspectives

Tant les milieux officiels que ceux du secteur privé se sont montrés intéressés par ce système, dont les essais en vol auront lieu vers la fin de 1987, une fois que les barrières administratives et juridiques auront été abattues.

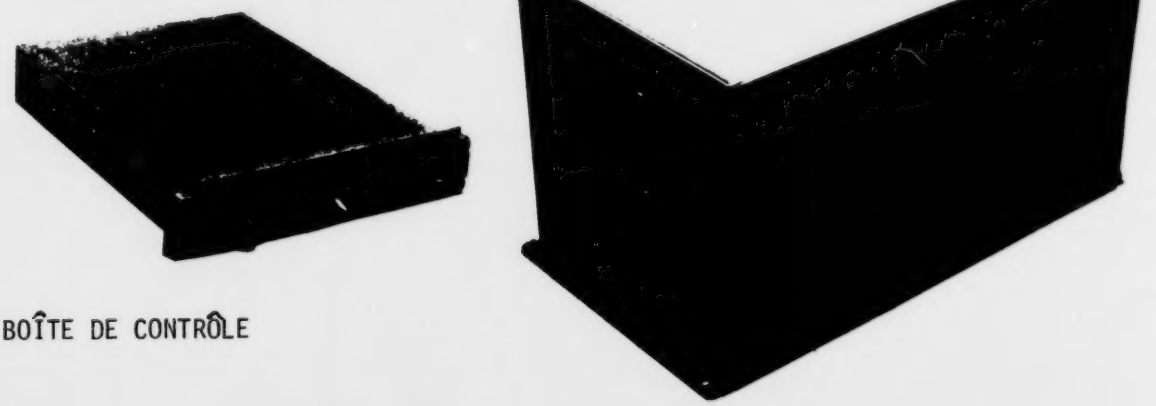
Un des problèmes particulièrement épineux est lié à la position des assureurs qui ont carrément refusé d'inclure ce système dans l'assurance responsabilité civile produit protégeant l'appareil dans lequel il serait installé. Les négociations durent depuis un an et rien n'a encore été résolu. Pour que les essais de vol puissent avoir lieu, il faut donc que l'exploitant prononce l'exonération totale. L'attitude des assureurs est difficile à comprendre étant donné que le système en question permet justement de réduire les risques d'avaries.

Le deuxième problème concerne la coopération du ministère des Transports pour la délivrance d'une licence autorisant les essais de vol en vue de la qualification du produit. Les choses en sont encore là, surtout pour ce qui est de la qualification. Il est à espérer qu'une solution puisse être trouvée sans avoir à se tourner vers les Etats-Unis pour obtenir la qualification là-bas, avant le Canada.

Des négociations sont en cours avec deux entreprises de transport par hélicoptères et avec la Garde côtière canadienne, en vue des essais de vol à bord de divers appareils. On s'attend à ce que ces essais débouchent sur des raffinements qui seront incorporés à la production série. Des simulations ont été faites en laboratoire et trois systèmes complets ont été réalisés dans le but de valider les matériels et les logiciels que l'on compte utiliser dans les essais de vol à venir.

Vue de certains équipements:

ORDINATEUR HSA-70



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1.0 HSA-70 Structural Design:

An analysis of the HSA-70 development platform requires an examination of two separate areas; the system hardware and the airframe profile software. In addition, an understanding of aircraft operation itself is also needed, in order to understand the overall purpose and relevance of the HSA-70 in operation. Readers are also directed to the phase one report, "Development of a Prototype of a Helicopter Voice Advisory System: VADIS", TP5461E, prepared by Northern Airborne Technology Ltd. for the Transportation Development Centre in May of 1984. It contains a more extensive treatment of aircraft design and operation, as relates specifically to the HSA-70.

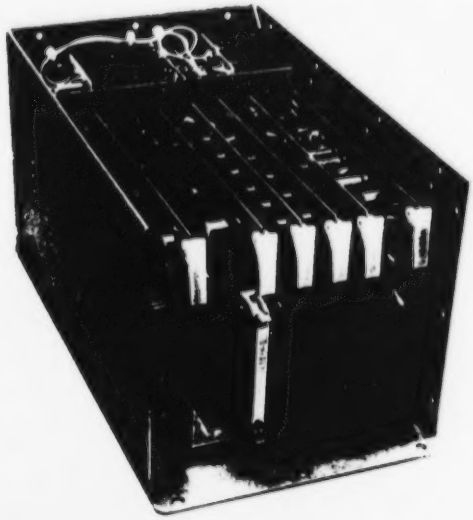
In the first phase of this project, an initial hardware solution was developed using a microprocessor with an integral Basic interpreter. Demonstration hardware was also developed for the analog and digital interfaces, and a simple laboratory demonstration simulator was constructed. This first pass at the VADIS platform revealed several system problems with regard to later software development, airframe interface, speed of execution, and chip availability. The solution presented in this summary is a much more refined and universally applicable hardware system, proven with complete airframe software.

During the second phase of this project, all hardware systems were optimized for speed and accuracy, and considerable attention was given to follow-on manufacturing costs and production difficulties. The resulting circuitry uses more generally sourced components, extensive use of mass termination techniques, and has been subjected to a comprehensive cost/value analysis. Software development has also been carried out in parallel with the actual hardware, to allow quick integration of required changes for full airframe functionality.

A complex bench simulator was also developed to exercise the VADIS system under realistic airframe conditions, and proved invaluable in defining and troubleshooting priority logic for messages under multiple fault conditions. At the end of phase two, actual computers (in a flight ready condition) were evaluated under the closest possible simulated flight conditions in the laboratory. These units are now ready for full flight testing in the target airframe (Bell 206 Jet Ranger).

The following structural design summary provides an overview of the actual detailed hardware implementation of the VADIS test platform achieved at the end of phase two.

HSA-70 Computer (Exploded View):



The hardware organization and construction of the HSA-70 computer itself is easy to understand if some key points are kept in mind:

1. Each required system task has been partitioned physically into separate circuit cards.

2. Dedicated processors have been provided for each major subsystem.

3. Over-all control of the system is held by the Z84C00 resident in the main computer chassis.

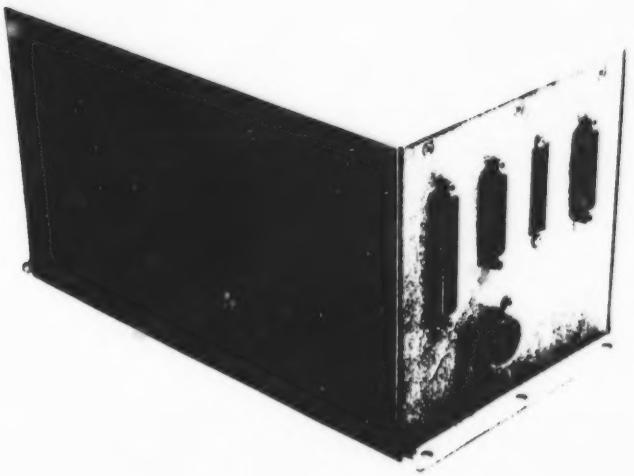
There are three microprocessors used in the HSA-70, one specifically for speech synthesis (54104), one for over-all system control (Z84C00), and one for control head functions (Z84C00). Both Z84C00's are under control of runtime code, with the main CPU interpreted by RASOR, and the control head processor running a simple assembly routine to control the switches and lights required. The speech processor, the 54104, is driven by internal microcode, and commands from the main Z84C00.

Physical interconnection is very similar for each microprocessor, with an outboard phase clock supplied, external memory and ports, and in the case of the Z84C00's, additional executable program storage.

All internal data manipulation is done via 8-bit words, and A-to-D conversion is also accomplished at an 8-bit level. Since 8-bit accuracy represents one part in 255 (.39%), this is more than adequate for the intended application, where existing data (temperature, fuel, torque) is presented typically to only +/- 3% accuracy.

Extensive use was made of CMOS technology throughout the HSA-70 to reduce power consumption and RFI. Hybrid technology, transformer coupled, isolation amplifiers from Analog Devices were used in portions of the analog sub-system to eliminate ground-loop interference when measuring low-level analog inputs. A similar optically-coupled isolation technique was used in the digital airframe interface to reduce interaction with existing circuitry.

HSA-70 Computer (External View):



2.0 Hardware Partitions:

The internal partitioning of the HSA-70 computer is accomplished in the following way to expedite assembly and testing, and for ease of upgrading and improvement:

1. Main CPU Card.....

   System CPU, main program storage RASOR interpreter, real-time clock, serial ports.

2. Power Supply Card.....

   DC-DC conversion, power-fail detect, RTC power back-up, reset.

3. Speech Synthesizer Card.....

   LPC processor, vocabulary storage, audio filters & amplifier.

4. Non-Volatile Memory Card....

   System NOVRAM and EEROM for data storage.

5. Digital Interface Card.....

   Airframe interface for 32 digital inputs (optically coupled).

6. Analog Interface Card.....

   Airframe interface for 8 analog inputs, thermocouple interface, tach generator interfaces (3). All 'floating' isolated inputs.

7. Interconnect Filter Cards...

   RFI filters for all I/O lines to and from main computer. Tamper interlock.

8. Backplane Card.....

   Physical interconnect for all plug-in cards. DC bypassing.

---External to Main Computer---

9. Control Head CPU Card.....

Control head CPU, serial port, displays and input interface, audio interlock and level adj.

Control Head View:

The physical layout of these cards conforms (in general) to the Mostek/ProLog STD BUS architecture, with the exception of a keep-alive DC line supplied for the RTC circuit, and the PSU card. The main computer itself is made of a card cage and backplane, and interconnect bay for external I/O. The control head is a DZUS mounted cockpit control, with the control head CPU card mounted inside, and interfaced to the main computer via a serial port connection.

3.0 Detailed Circuit Analysis:

In the development of this system, there were several critical design problems which posed major difficulties for the design team. The largest of these was the development of a suitable microprocessor base and matching fast interpreter to form the control section of the VADIS system. This also required quick manipulation of A/D conversion and extended memory areas, and interrupt handling with software masking. The development and final design of this hardware sub-system is covered in section 3.6.

The A to D sub-system was also a challenging and complex design, and eventually made use of the latest technology in hybrid isolation amplifier design to pack the complete system (eight channels) onto a single card. A unique optically-coupled digital tachometer was also developed to provide high resolution of low frequency engine tach-generator waveforms. All of the data sampled by this card is done via fully isolated techniques, to prevent interaction with existing aircraft systems.

The speech synthesizer was well developed during the first phase of this project, and later phase two development work only refined the quality of speech and expanded the resident vocabulary base. The final synthesizer has both high intelligibility and low system overhead, freeing the main CPU for other tasks within the VADIS system.

Efficient power conversion from airframe 28 VDC power to usable system voltages was accomplished via a very high frequency switching coverter, and support logic for power fail/brown-out detection. This allows the computer to function with little waste heat generation, and very low input power consumption.

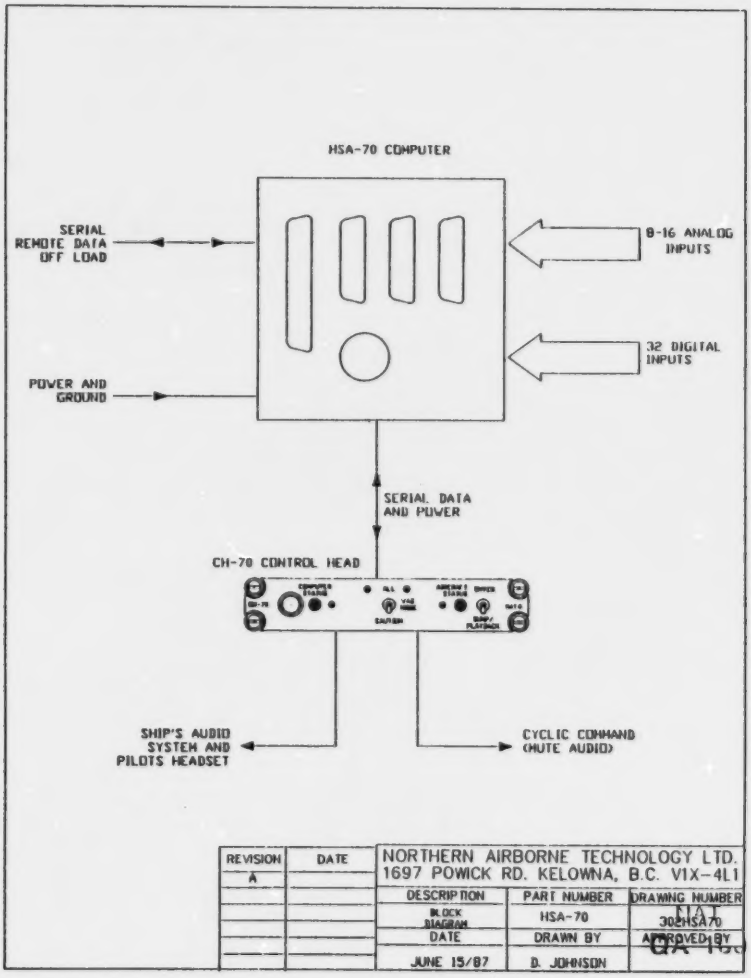
The performance and capability of the control head (which provides the only visible interface to the pilot) was greatly improved and enhanced during phase two development, and system growth through visual data presentation was also designed in (LCD display). The total system can now provide fault data both visually and verbally, and service editing and data recovery have been made easier through functions of the local CPU.

All main interconnect has now been achieved through either backplane or mass terminated techniques (section 3.7), which makes the final system design more practical to manufacture and assemble.

A brief circuit summary, schematic diagram and physical view of each sub-assembly or card follows, to provide better insight into the physical makeup of the HSA-70.

Where signals are referenced back into the computer, they refer to signals on the backplane, which are bussed in parallel to each card within the computer. Outgoing signals refer to lines exiting the computer, and connected to the airframe or control head.

System Block Diagram:



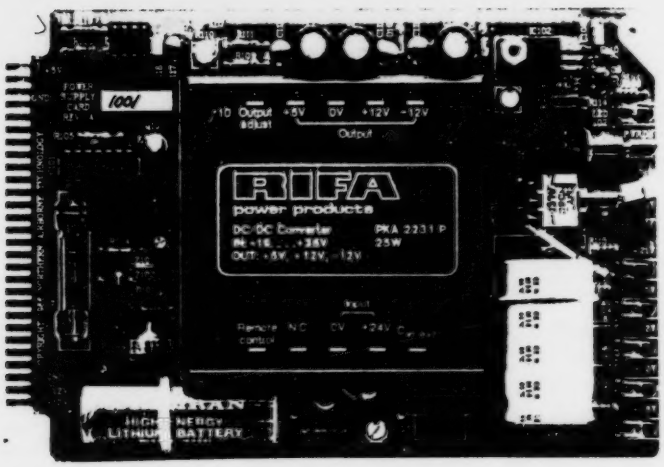
3.1 Sub-system: POWER SUPPLY

The power supply card provides all system voltages and master fault detection/power fail signals. It obtains a nominal +28VDC input from the airframe electrical system, and converts this into +5VDC, and +/- 12VDC. Conversion is accomplished via PC101, which is a high frequency DC/DC converter providing 25W of energy conversion.

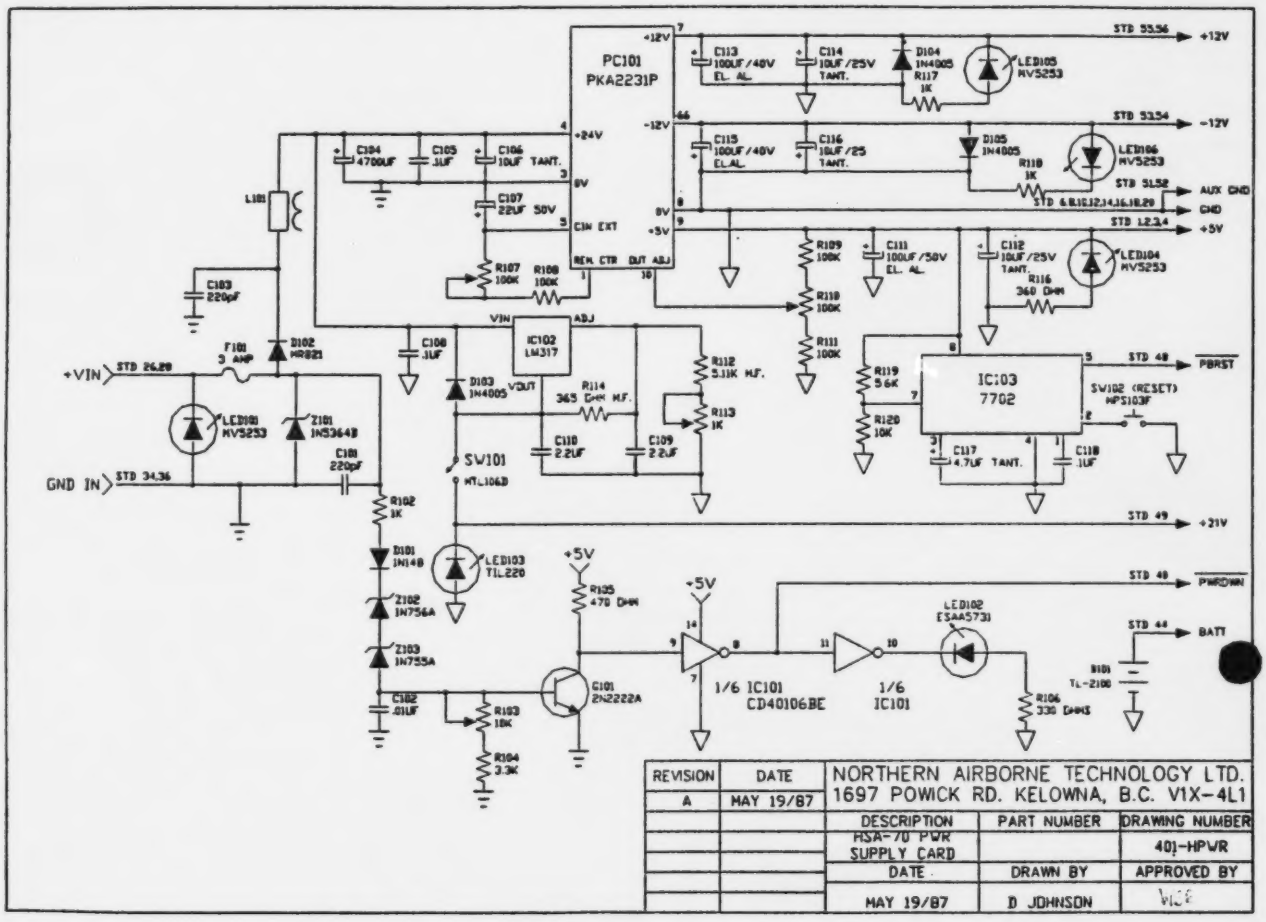
Because the airframe electrical system is heavily loaded during engine start up, a charge reservoir is provided by D102 and C104 to prevent loss of conversion momentarily. If the input should fall too low, the voltage sensor associated with Q101 and IC101 outputs a signal to the computer advising that input failure has occurred, and insures a clean power-down and data storage cycle before +5VDC failure occurs.

Loss of +5VDC is sensed by IC103, which further aids in the orderly shut down of the computer and final NOVRAM writes. Battery back up for the real time clock (RTC) is provided by a lithium primary cell (B101) which is diode switched to the RTC +5VDC line. This insures no loss of time to the perpetual clock. IC102 provides +21VDC that is used only for EPROM programming when the HSA-70 is used to develop its own programs. There is one PSU card per computer.

Board View:



Sub-system: Power Supply **Internal Schematic**



REVISION	DATE	NORTHERN AIRBORNE TECHNOLOGY LTD. 1697 POWICK RD. KELOWNA, B.C. V1X-4L1		
		DESCRIPTION	PART NUMBER	DRAWING NUMBER
A	MAY 19/87	HSA-70 PWR SUPPLY CARD		401-HPWR
		DATE	DRAWN BY	APPROVED BY
		MAY 19/87	D JOHNSON	

3.2 Sub-system: ANALOG INTERFACE CARD

The analog card provides four different types of interface into the computer, thermocouple (1), tach generator (3), absolute temperature (1), and variable level DC (3). These signals are converted to 8-bit digital words through U4, which is a self-multiplexed 8 channel 8-bit A-to-D converter. U4 obtains its clock via U14, and its addressing and functional enable lines via U1 and U2 and associated gates. The master volate reference for U4 is obtained from U3, which is a high stability monolithic band gap reference set to +5.12VDC (making each interval equal to 20mV).

The thermocouple interface is accomplished via U22 (lov level amplifier) and U19 (isolation amplifier). A reference temperature figure is derived via U17 and its associated circuitry from an external AD590 temperature sensor. This is used for both OAT data and cold junction compensation in software.

U18, U20 and U21 are isolation amplifiers which sample the values of Fuel Pressure, Fuel Quantity, and Torque inputs respectively. They respond to changing DC input levels.

Tach generator inputs are first optically coupled via U23 through 28 to produce clean isolated square waves of the same frequency as the lov frequency (typ. 30 Hz) sine wave input. These are sharpened by U3, and run into U6, which is a data selector. Latch U7 stores the specific address of the waveform desired, which in turn gates on the appropriate input from U6. This is then run through the counting loop of U8, U12, U9, U10, U11 and U13 to produce two 8-bit counts representing the period of the waveform digitized in increments of the clock developed by U14. This provides very high resolution of small changes in frequency produced by the airframe tach generators.

Data is read by the main CPU via the data lines D0-D7 either from the A-to-D converter, or from the latched counters, U10 and U11. Control over each analog function, and which data is presented is accomplished via gating of the IORQ line, RD, WR and appropriate port addresses. Up to two analog cards may be installed in each HSA-70, with appropriate changes in the decoding of U1.

The transformer coupled isolation amplifiers used to provide ground isolation require a stable 15VDC supply, which is in turn used to drive their common AC clock generator (U16). Because there is no +15VDC available from the backplane, U15 is used as a charge-pump oscillator/voltage doubler and regulator to develop a stable +15VDC to drive U16. This is especially

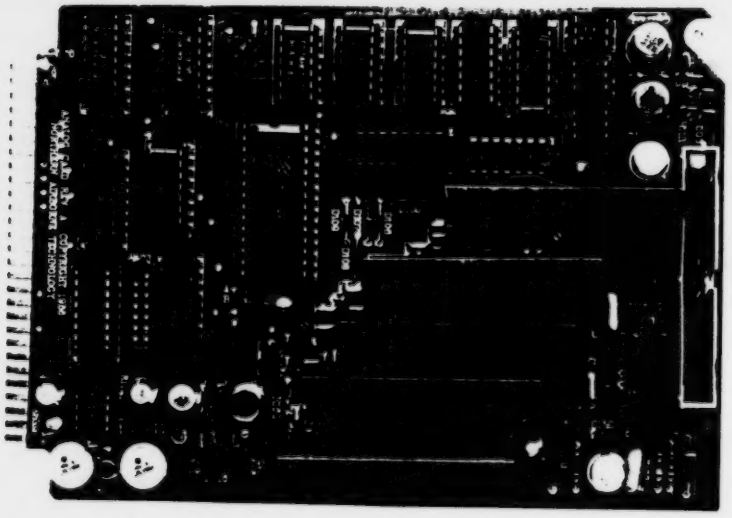
important, as the system +12VDC is only a secondary, partially regulated line, and exhibits significant variation during normal operation. The use of U15 to create this stable higher voltage assures that no degradation will occur on any analog lines due to internal supply variations.

The isolation amplifiers also produce their output by an integration of the AC component passed through their coupling transformer, and this may introduce some artifacts which result in bit errors during conversion. Passive low pass filters are inserted between each amplifier and U4 to prevent this effect, and insure conversion stability.

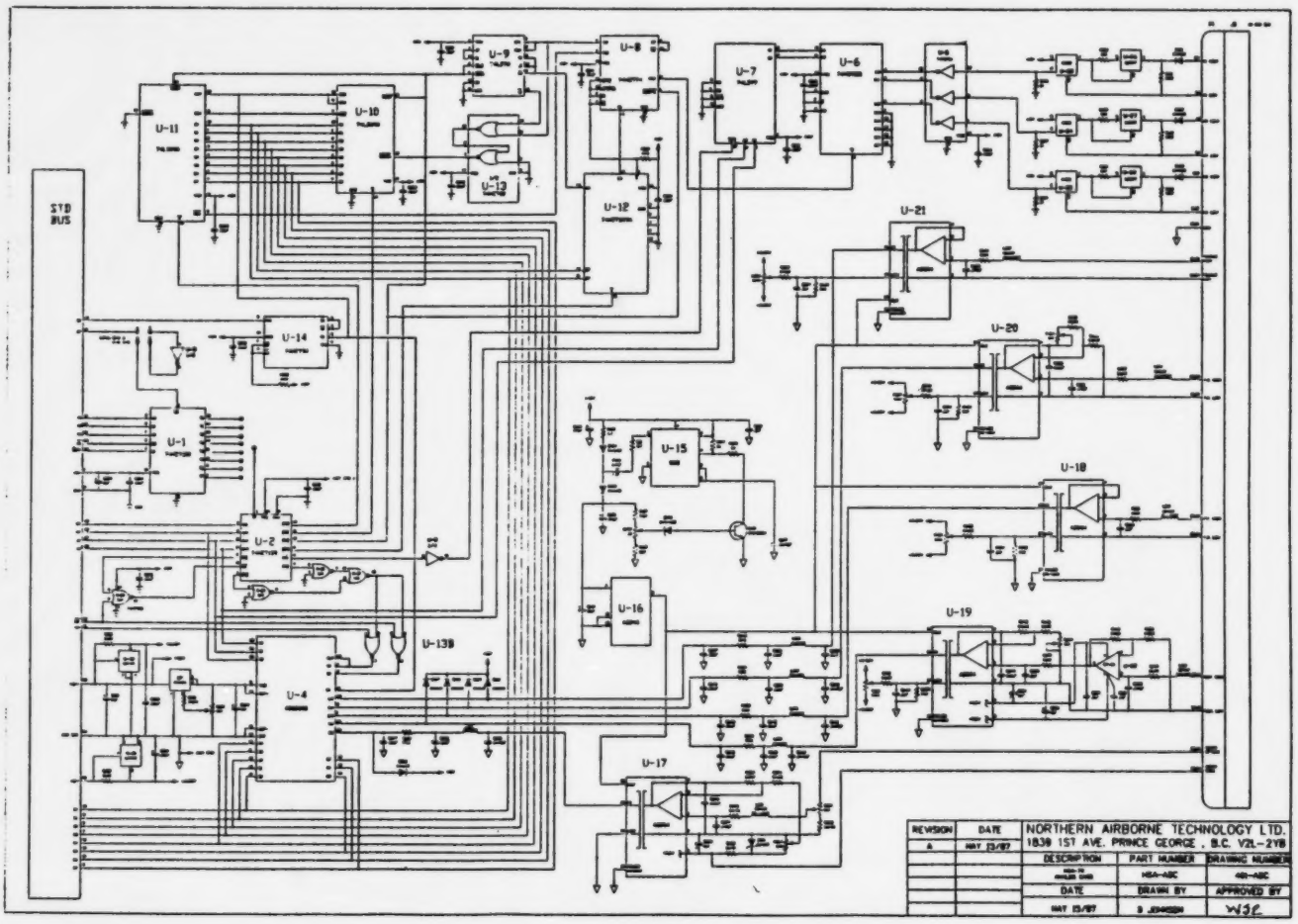
The isolation amplifiers also provide low current +/- 7.5VDC on the input side of the isolation winding. This is used by the thermocouple and absolute temperature interfaces to drive special input-referenced circuits as needed. U22 is used in this manner to improve the low level performance of the thermocouple channel, by providing more temperature stable gain, thus reducing drift.

Zero biasing for each channel is provided where required to insure elimination of offset errors before conversion. The voltage to drive this correction is obtained from highly stable and temperature compensated voltage references (U30 and U31).

Board View:



Sub-system: Analog Interface Card Internal Schematic



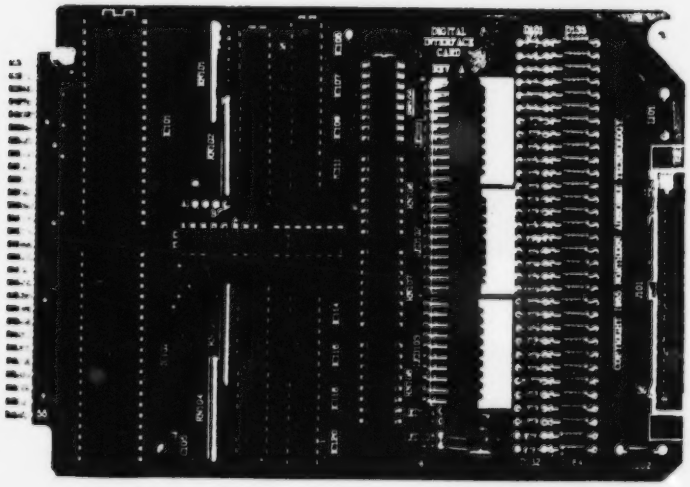
3.3 Sub-system: DIGITAL INTERFACE CARD

This card provides optically coupled and isolated interfaces to 32 airframe digital inputs. These may be switch closures, pressure switches, relay contacts, etc., which are normally referenced to the airframe voltage supply and ground. These lines are typically referred to as 'ground seeking' inputs, in that they are grounded to be active or asserted. In the airframe, they typically drive caution lights or sonalerts for alerting the pilot to fault conditions. Two channels are provided which are voltage seeking, and thirty which are ground seeking.

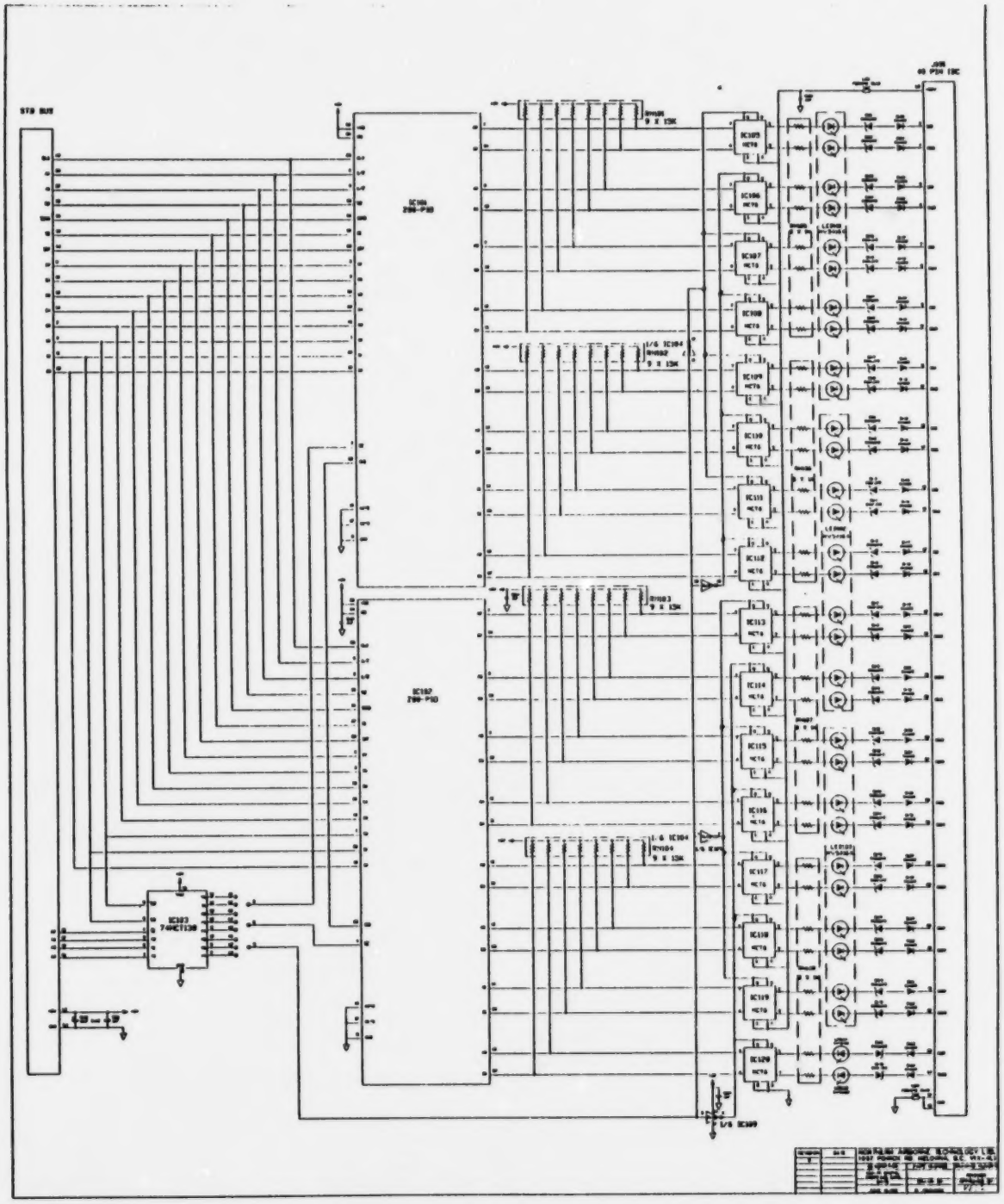
These lines are coupled through D101-D132 (zeners) D133-D164 (rectifiers) into dual optocoupers (IC105-IC120), visible warning LEDS (LED101-LED105) and current limiting resistors (RN105-RN108). This results in high noise immunity, wide operating range, and lack of interference with existing annunciators. The outputs of the dual optocouplers are pulled up through resistor networks (RN101-RN104), and interfaced to the microprocessor bus via two PIO's, IC101 and IC102.

Port addressing is accomplished by IC103, and IC104 is used to reset the PIO inputs from the optocouplers to assure correct interrupt servicing from the host CPU. Only one digital interface card is used in the HSA-70.

Board View:



Sub-system: Digital Interface Card Internal Schematic



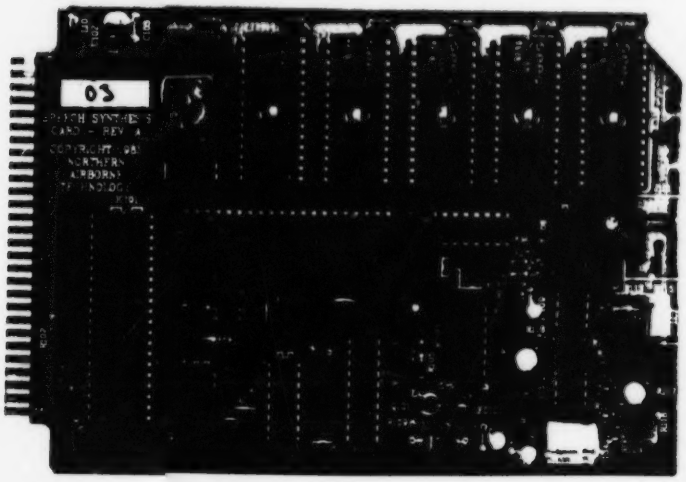
3.4 Sub-system: SPEECH SYNTHESIZER

This card is used to convert the hex codes from the main CPU into spoken words. Interfacing between the main CPU and dedicated LPC processor (IC102) is accomplished via an on-board PIO (IC101), and additional latched commands stored in IC105. The specific port allocation is set by IC104, and the LPC processor clock is produced by X101 and IC103 (4 MHz). Once a code is input to the LPC processor, it functions as an independant system, and controls all aspects of the speech generation process without main CPU intervention.

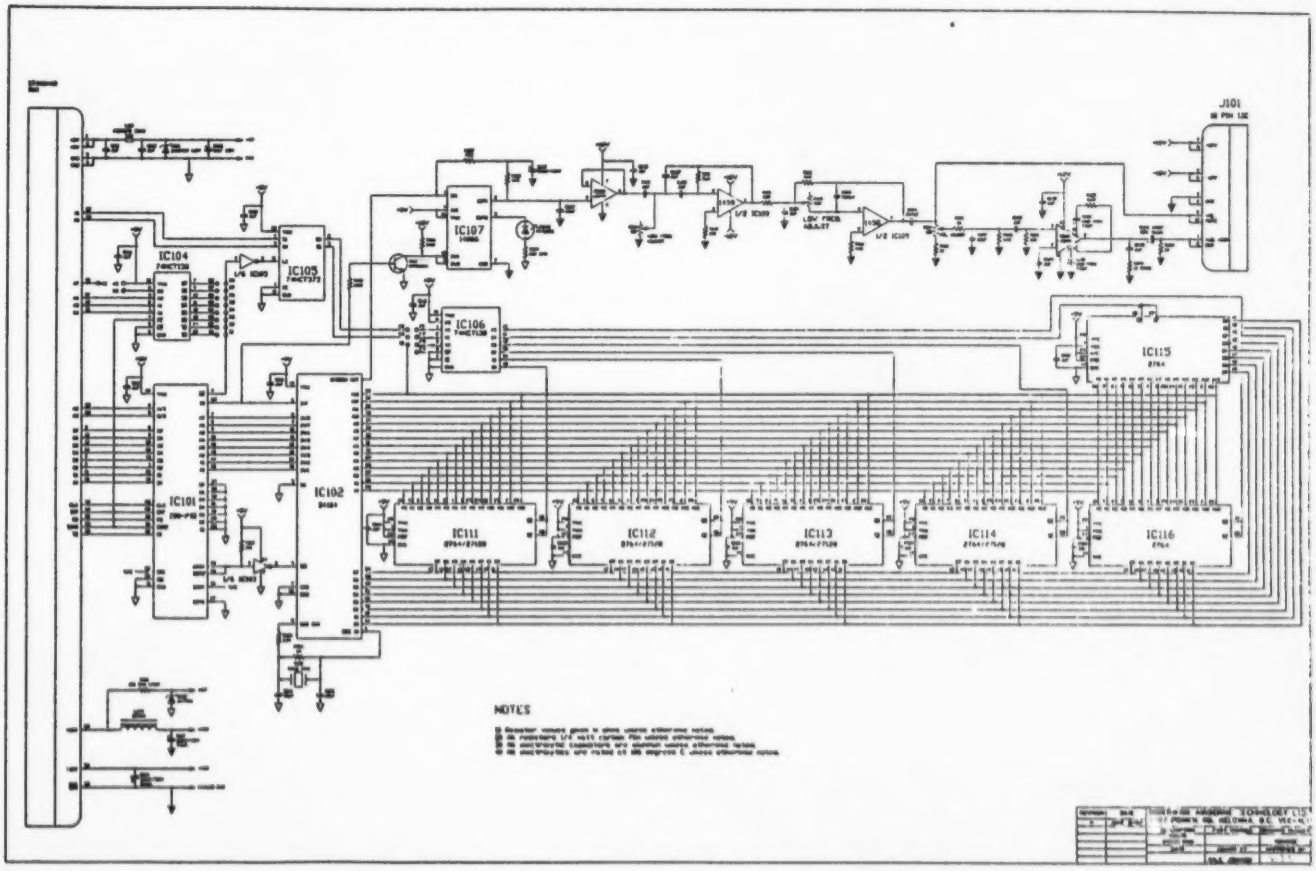
The actual synthesis is performed by IC102 in conjunction with EPROM vocabulary storage in IC111-IC116. The digital codes for words are translated by the 54104 into LPC segments recalled from EPROMs, and output as a serial stream into the filters created by IC108 and IC109. These filters remove objectionable switching artifacts, and provide adjustable tonal control for voice optimization. The final output is sent through IC110, which is an audio power amplifier, and from there out into the airframe's audio system.

To reduce background noise, IC107 is wired as an audio transmission gate to block all output except during active speech generation by the 54104. IC106 provides chip select signals for expanded EPROM vocabulary storage. Only one speech card is used in the HSA-70.

Board View:



Sub-system: Speech Synthesizer Internal Schematic



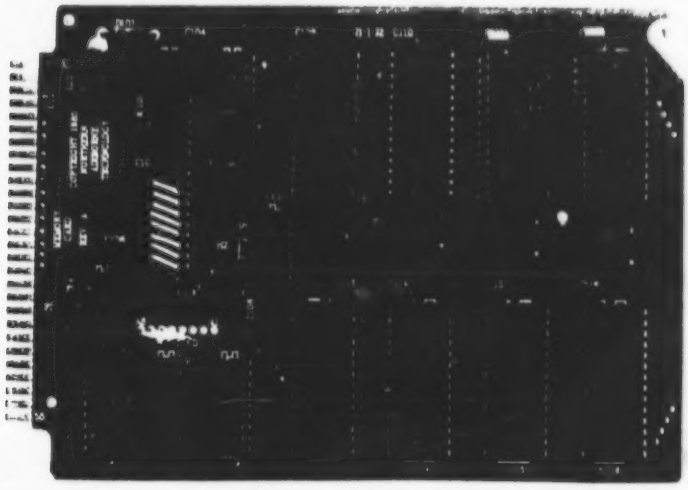
3.5 Sub-system: NON-VOLATILE MEMORY CARD

This card provides two types of non-volatile memory for the main CPU, fast NOVRAM (or 'shadow' RAM), and bulk storage in EEROM. The NOVRAM (IC107 and IC108) is capable of essentially unlimited high speed read/write operations, and is used as the system 'scratchpad' storage, keeping track of start cycles, power-on hours, and other counters which are constantly updated. Data is transferred as one massive write during the power down cycle from the high speed RAM to background EEROM storage within the NOVRAM.

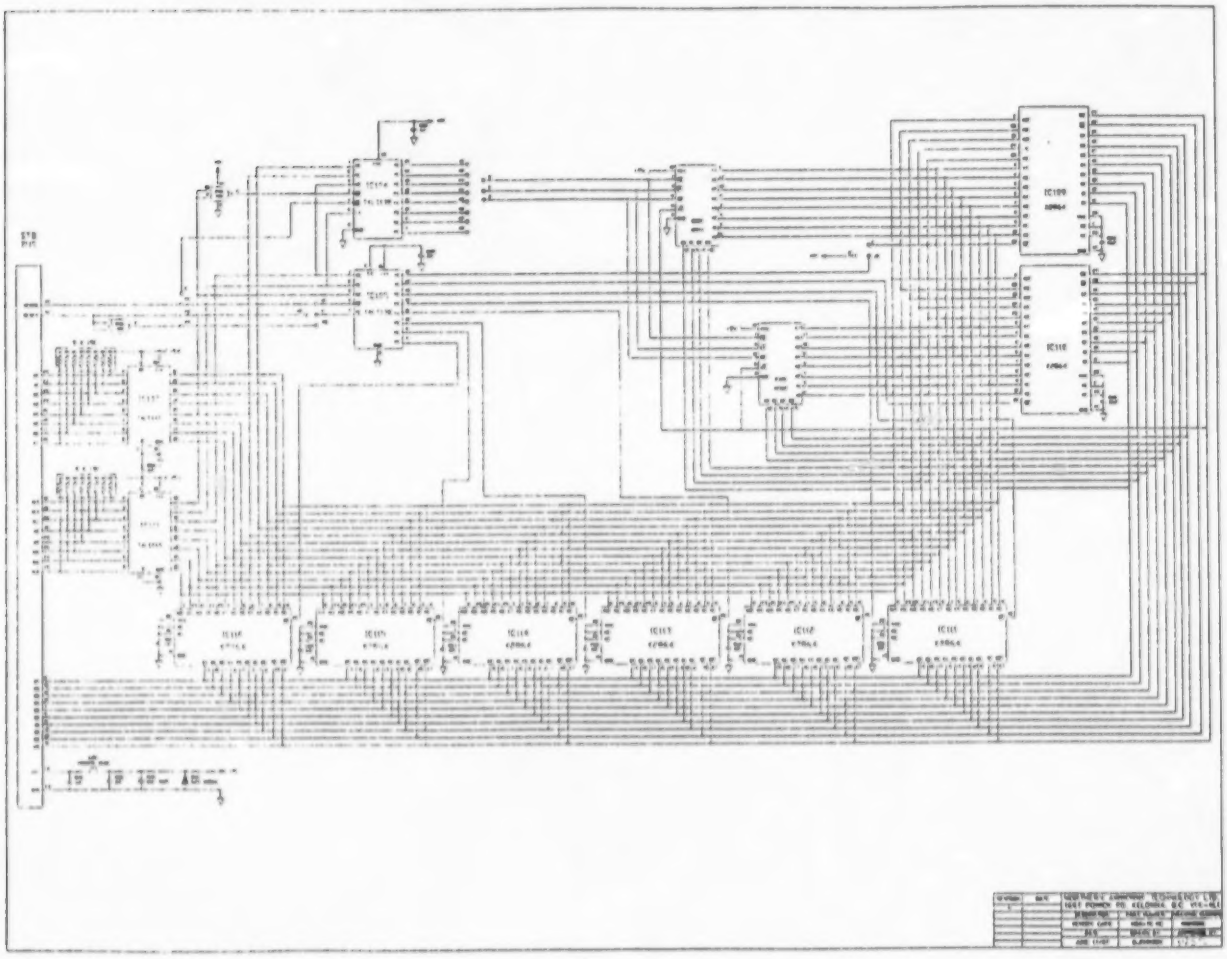
Much larger storage is provided by the limited write capability EEROM storage (IC109-IC116), which is optional in the computer. This is used to record all fault data in sequential order, along with time stamp information. Up to 64K of storage is possible (in increments of 8Kx8 per chip). The parts used for this function are 'self-timed' and provide stand-alone write operation without further intervention by the main CPU. This is very important, as EEROM write cycles are very long (10-100 mS), and would tie up the CPU if not self clocked internally.

The other chips provide the usual address selection and address buffering, and provide for alternate card locations. While only one card is required for operation, additional cards could be used for expanded fault storage, with some software modification.

Board View:



Sub-system: Non-Volatile Memory Card Internal Schematic



3.6 Sub-system: MAIN CPU CARD

The main CPU card contains all the centralized control for the HSA-70 system, including airframe program storage, primary CPU and support, and RASOR interpreter. It assumes control of other sub-systems via connection through the backplane, and to the remote control head via its serial port connection.

The physical organization of this card allows the Z84C00 to have various amounts of SRAM/EPROM storage, depending on the actual requirements of specific airframes. At least one block of SRAM is required for CPU stacks and variable storage, and is normally located in position IC107. The normal configuration of this storage is 8Kx8.

The RASOR interpreter is stored in an 8Kx8 EPROM in location IC106. This is required in all versions of the unit, and provides the command interpreter for all airframe oriented software.

The airframe diagnostic program is stored in 8Kx8 or 8Kx16 EPROMS beginning at IC108, and optionally extending to IC109. Socket IC108 can also be programmed by the CPU via program control, the timing of IC123 and a power supply switch change. This allows the HSA-70 to serve as its own development station, if the second serial port is used with a terminal.

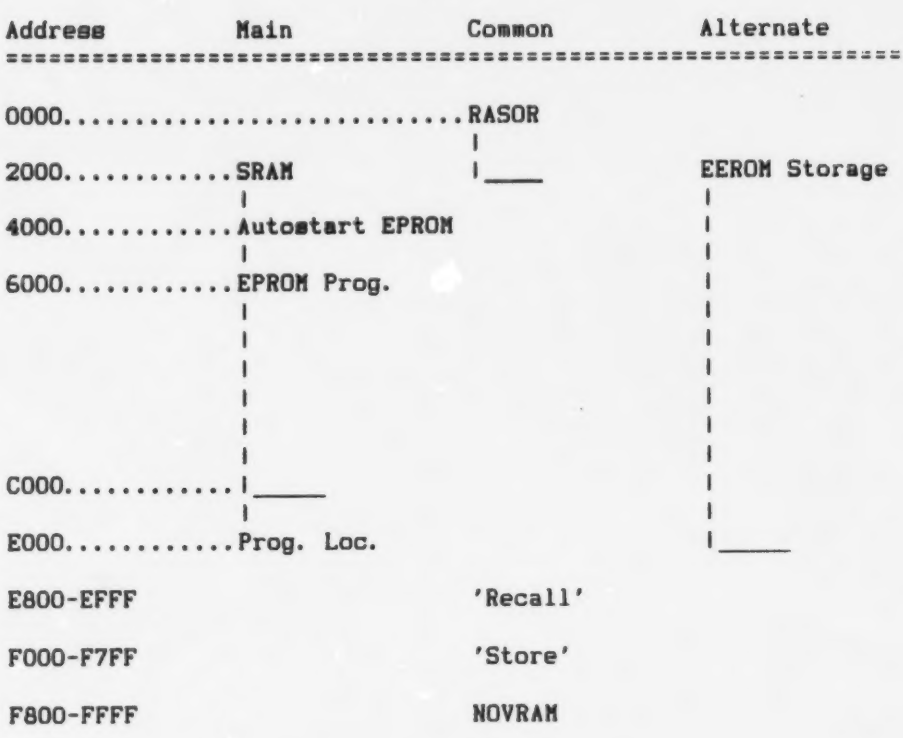
There are three memory areas within the HSA-70 main CPU organization:

1. Main Memory (executable programs)
2. Common Memory (interpreter and NOVRAM)
3. Alternate Memory (storage)

These three are interleaved as shown in the following memory map to give expanded storage for the 8-bit processor, and fast power-down or storage control. Port locations are used internally to switch between banks, which is accomplished via IC120-IC122. Common areas represent code which must be common to both zones in order to accomplish program execution.

The non-volatile memory card can be set up in several different configurations, which is why there are only six 8K bloks of EEROM shown on the memory map, but eight sockets on the board. The space taken by the NOVRAM or common RASOR code can be re-mapped to those sockets, if needed in a specific application.

---Memory Map---



Physical partitions are normally on 8K blocks, but can be altered to 16K in some physical positions on the main CPU

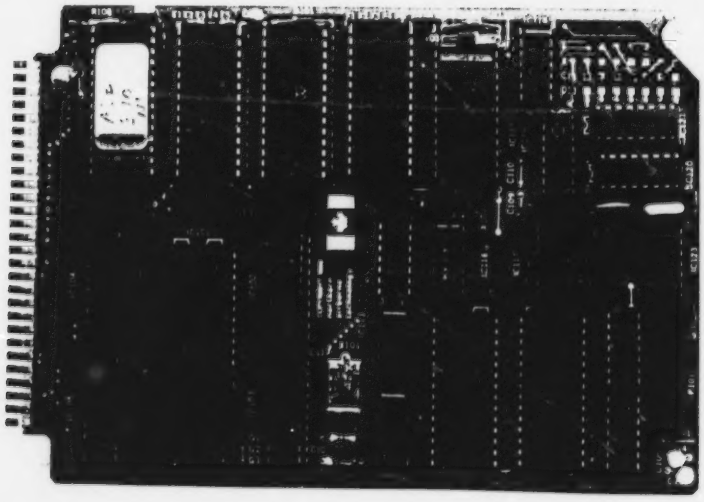
Dec. Address	Hex Address	Description	138 Pin#
0-15	00-0F	A/D Card (#1)	15
16-31	10-1F	A/D Card (#2)	14
32-47	20-2F		13
48-63	30-3F		12
64-79	40-4F	Digital I/O (PIO #1)	11
80-95	50-5F	Digital I/O (PIO #2)	10
96-111	60-6F	Digital Card Interrupt Reset	9
112-127	70-7F	Speech Card	7
128-159	80-9F	Main Serial Port (Terminal)	11
160-191	A0-BF	Aux. Serial Port (Control Head)	10
192-223	C0-DF	Real Time Clock	9
224-239	E0-EF	Main Memory Bank Select	
240-255	F0-FF	Alternate Memory Bank Select	

The balance of the main CPU card is somewhat simpler to explain. The main clock is developed by a 4.9152 MHz crystal and IC114, and is used to provide the baud rate reference clock to the two serial I/O controllers, IC112 and IC111. This fast clock is then divided by IC113 to provide a nominal 2.45 MHz clock for the CPU itself. A third clock is used by the RTC, and is a low frequency crystal (32KHz) that is used directly by the RTC's internal oscillator.

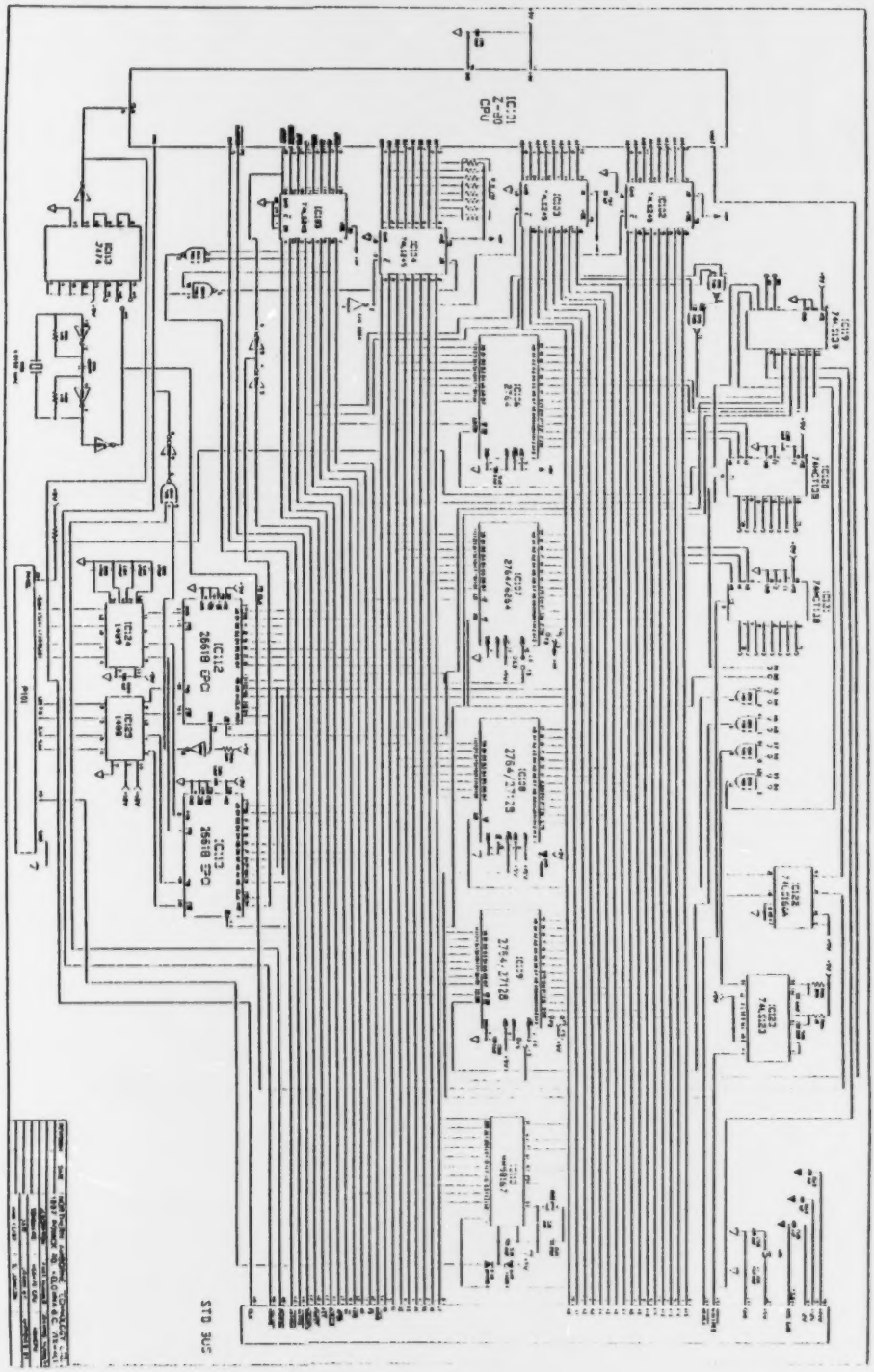
IC103-IC105 provide buffering for the address and data lines to the CPU, and insure sufficient drive is available to service the backplane. The RTC is powered either by the system +5VDC, or by the battery back-up provided by the power supply card. This insures correct running time is retained by the system.

The serial I/O controllers (EPCI's) are connected to other systems via IC124 and IC125, which provide levels compatible with RS-232C standards. This allows use of an external terminal or other device for data loading or dumping. Connection to the external interfaces is provided through an IDC connector at the edge of the card, not via the backplane. Either a passive Rc power-on reset can be used, or the system PBRST command generated from the power supply card. This resets both the CPU and serial controllers to insure correct system start-up.

Board View:



Sub-system: Main CPU Card Internal Schematic

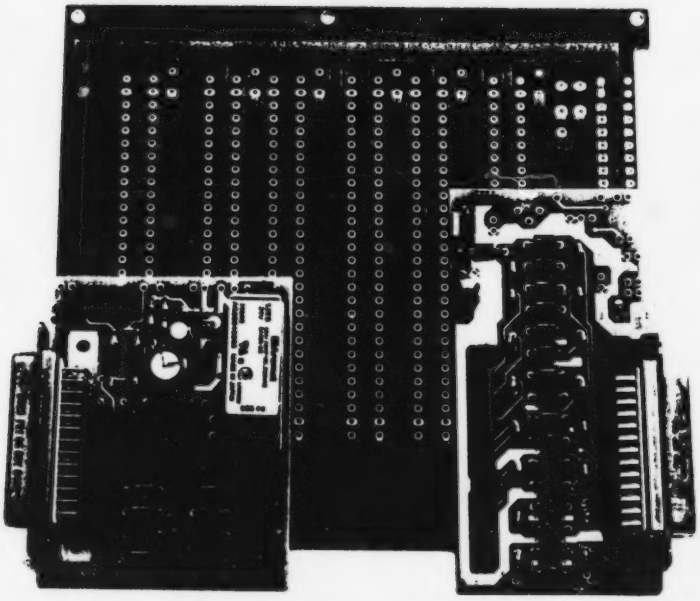


3.7 Sub-system: INTERCONNECT & BACKPLANE CARDS

These cards provide the physical interconnect between other modules, and the transition between IDC cables and external connectors. Their circuitry is quite simple, and usually consists of nothing other than connectors, with some filtering and bypassing as required.

On the cards used to carry the analog and digital inputs to the computer, RFI pi filters with ferrite beads are used to suppress radiated interference from the HSA-70 itself, and prevent these signals from interfering with other aircraft systems.

Board Views:



3.8 Sub-system: CONTROL HEAD CPU CARD

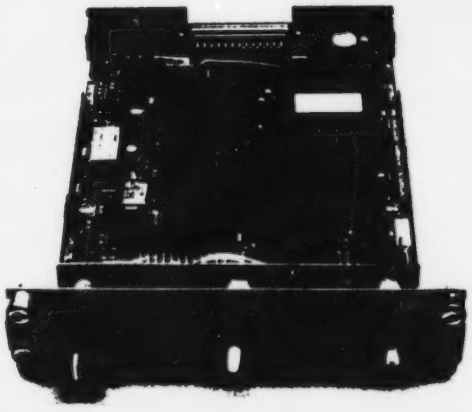
This board is a somevhat scaled dovn version of the main CPU card, and also contains all the front panel controls and indicators used by the pilot in flight. Muting of the output audio is also supported here, in the event the pilot needs to suspend messages because of other urgent cockpit activities.

The Z84C00 CPU (U102) is clocked by a divied bit rate clock, as in the main CPU, and the full clock is used to provide the bit rate reference for the serial controlller (U105). Serial I/O is translated to RS-232C levels by U107 and U106, and used to communicate with the main CPU in the HSA-70.

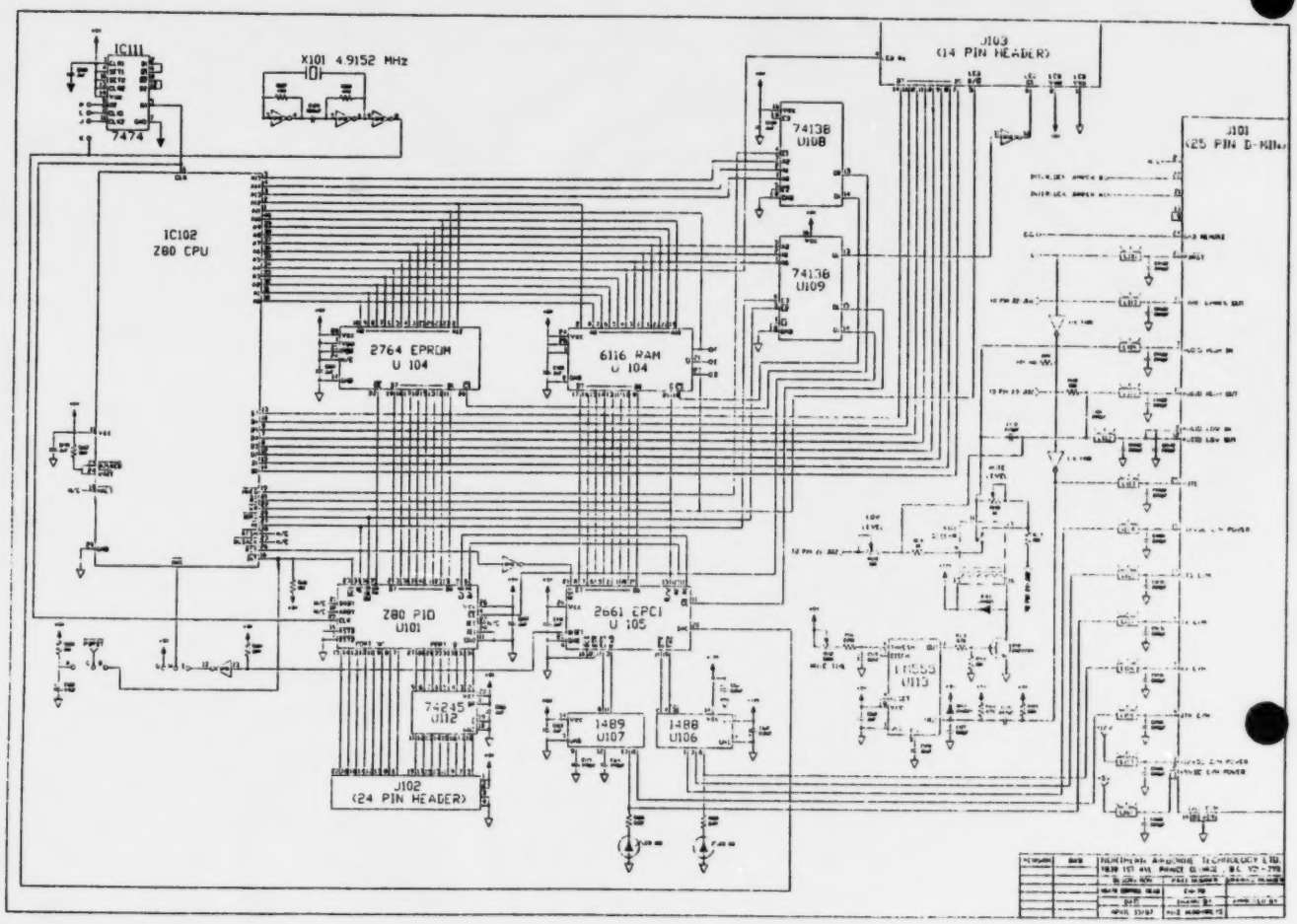
EPROM and SRAM storage is provided for the required assembly routine and variable/stack storage needed by the CPU. A PIO circuit (U101) is provided for the parallel interface needed to run the front panel controls/indicators on the face of the control head. U108 and U109 provide the address decoding for the devices on the control head card, and an external interface for later expansion to an LCD display.

An audio over-ride is provided, which is triggered by the pilot (from a cyclic switch). This allovs short-term muting of the audio during situations where it is an interference to the pilot. To accomplish this, U113 drives K101, which interrupts the audio feed from the HSA-70, and provides a timed mute. All audio through the control head is floating from the digital ground, to eliminate interference and noise. A front panel level adjustment is provided for over-all audio level heard by the pilot. All pover used by this board is supplied by the power supply within the main computer.

Board View (inside control head enclosure):



Sub-system: Control Head CPU Card **Internal Schematic**



4.0 Software Overview:

The actual airframe programs themselves are written in a language developed by NAT and Arctic Data, called RASOR. This provides strong control of hardware level operations with the form and syntax of 'Basic' like commands rather than assembler. This is a very important consideration, as airframe software must be easily created, maintained and ported to new ships without exhaustive re-writing. Code written in assembler would be almost impossible to work with in this manner.

Program structure itself is very simple as a result of RASOR, and consists of three basic parts:

1. Data collection routine.
2. Error recognition.
3. Annunciation and storage of fault data.

A sample program is included here, written for the Bell 206, which illustrates the over-all program flow and syntax used in the HSA-70. Because this code is INTERPRETIVE, it is possible to edit it directly under control of the HSA-70, as well as examine it in clear form. This is a considerable benefit where diagnostics and program enhancements are concerned.

A strong understanding of both the airframe priorities and hardware priorities within the computer is needed to fully appreciate the structure of programming for the HSA-70. This is quite beyond the scope of this explanation, but interested persons are directed to the applicable Bell flight manuals for the airframe, and detailed data sheets for the Z84C00 series of peripheral devices to understand the interlock and interrupt relationships that exist. In general, it is sufficient to say that internal hardware priorities are always geared to service the most serious airframe faults first.

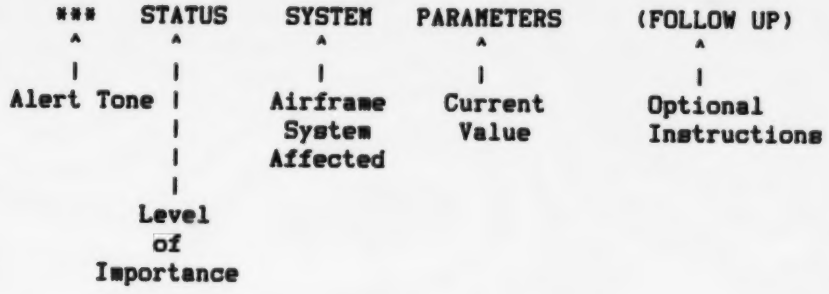
The software must take into account the fact that some events are more serious than others in terms of pilot importance. There are also many events, such as engine failure, or rapidly decaying main rotor RPM, where the time interval between detection and advisory must be short and the message succinct, or the aircraft will crash or be fatally damaged while the computer is still trying to make itself heard and understood.

This system is also not a REPLACEMENT for existing systems, but rather a SUPPLEMENT to them, providing improved pilot recognition of the fault, and hopefully better follow-up rectification. The computer provides an immediate voice message for the pilot, with re-circulating reminders on lengthening

cycle times, and storage of the fault and times for later examination.

4.1 Message Structure:

Message structure has been the subject of considerable discussion between NAT and flight line personnel, and the final format is shown here, in general form:



The ALERT TONE is a very brief tone or tone sequence used to quickly catch the pilot's attention. Experiments show this improves recognition of the fact that the following sequence is a warning message.

The STATUS is a one word summary of how important the message really is. There are three categories at this time:

CAUTION.
WARNING.
EMERGENCY.

The SYSTEM identifies which airframe system or component is affected by the message. Examples would be:

FUEL CONTENTS
ENGINE
TORQUE

The PARAMETERS field provides a more definitive explanation of the SYSTEM information, and may have either a numeric value or word inserted. Examples would be:

LOW
FAILURE
108%

The FOLLOW-UP or TRAILER message may contain such advice as "land within 30 seconds", or other directive to the pilot. At this time, this function is not in use, as there is some legal question over the advisability of providing this data to the pilot.

4.2 Language Commands:

Speech is handled in software by identifying the words (and silences) required for the message, and then outputting that code to the LPC processor, which in turn handles the actual re-construction of the digitized human voice by LPC techniques and the stored digital segments stored on the speech card. This is done via port control commands (to select and control the hardware operation of the speech processor).

In some cases, the exact words needed are made from pieces of existing digitized speech, and the sequence will then be interrupted by the main CPU, and restarted, to achieve some degree of phoeneme synthesis. The total storable vocabulary within the HSA-70 is approximately 500 unique words or sounds.

As will be seen from the following code listing for the Bell 206, extensive use is made of recursive loops and sub-routines to reduce code size.

Guiding remarks as to code function are marked "REM" in the left margin, and are not executed. Variable names are limited to two characters, but arrays/subscripted variables are supported (ie., S1(3)). The commands "PUSH" and "POP" have the same function as their assembly commands, the "OUT" statement talks to an I/O port. The "INP" statement reads a port. "INTON" enables hardware interrupts. "GETTIME" is a clock read function (macro). "STORE" is an EEROM store data command (macro). Other commands are as in Basic. As can be seen from these examples, hardware control is achieved at assembly levels without assembly coding.

Other easily recognized commands are from Basic, and include IF/THEN, PEEK/POKE (direct memory read/write), GOSUB/RETURN, GOTO and math operators (< > * / + -). Commands are evaluated from left to right, and the colon (:) allows multiple commands on a single line.

5.0 Software Implications:

The program structure reveals a great deal about the approach used in the HSA-70. As can be seen, tailoring the system for new aircraft is largely a matter of limit table or message editing, and does not require wholesale re-design of the software structure. This is a very important consideration with regard to ease of porting, and software validation, as the workload of the programmer is greatly reduced by this method.

Use of assembler would have marginally improved speed, but would have resulted in almost incomprehensible (and un-relocatable) code, with much higher maintenance costs. RASOR can be run on any Z80 compatible CPU, and allows modelling or test runs with comparative ease. The service routines in RASOR also allow the computer itself to be used as a development station, with the ability to run and edit code, burn EPROMS, and examine operation in the halt or step mode. External devices, such as a terminal, are serviced through the serial port for this function.

There is little benefit to be gained through increased word size beyond 8 bits (which implies improved resolution and accuracy), as the existing 8-bit increment is 0.39%, which is much better than the basic systems in the aircraft. What, for example, is the point in displaying torque values as 108.94% if the sensor can only achieve repeatable accuracy of 2-3% ? There is often a strong conceptual bias here, in that many people seem to feel that endlessly increasing 'accuracy' is an improvement under all circumstances. In the case of the HSA-70, this is seen as gratuitous time wasting, since there is little chance (due to primary sensor accuracies of 3% typical) that the figures will be accurate to several decimal places, or that there is any benefit to obtained.

The system could be ported to 16-bit processors if there was felt to be some other benefit, and RASOR can be re-compiled to work under similar 16-bit environments (8088/8086) with only a small amount of work. By the use of bank switched memory, the 64K memory limitation usual to 8-bit microprocessors has already been overcome in the HSA-70, so the benefits of such a hardware upgrade are uncertain at this time.

Some additional macros may yet be added to RASOR to shorten code length for often used functions. At this point, the RASOR interpreter is about 7.5K in length, which allows it to fit into a single 8K EPROM, and easily into the system architecture. Further enhancements will have to keep this practical limitation in mind when upgrading interpreter functions.

6.0 Future Directions:

The next major phase of this project involves flight testing and certification, which, as discussed earlier in the summary, poses some procedural difficulties. It is expected that these will be overcome, however, and some level of commercial production is expected by the first quarter of 1988.

Flight testing and certification qualification will be carried out using the three computers built under this project. Some level of FAA-TSO certification or STC will be required to allow aircraft installation both in the US and Canada. How this will be obtained (much simpler from the US) has not yet been determined, as negotiations to accomplish this are still underway with the MOT.

There is interest in the HSA-70 in a variety of applications, both airborne and land based. These include:

1. Use in the new NSA helicopter program (Canada).

2. Use in monitoring large truck operations for mining.

3. Use as warning system for mill operations.

NAT will be actively involved in these market areas with the HSA-70, and derivative products.

Appendix: Sample Software Program

---Sample Airframe Program Listing---

(Bell 206 Jet Ranger)

```
REM     MAIN HSA70 PROGRAM FOR 206 DEMO
REM     MONITORS 8 ANALOG AND 32 DIGITAL LINES.
REM     ORDER OF PRECEDENCE (HIGHEST TO LOWEST):
REM     T.O.T., D0-D7, TORQUE, D8-D15, TACH1-3, D16-D23,
REM     FUEL QTY/PRESS, D24-D31, TEMPERATURE
REM     WORD LISTS USED: DEMO87-1, DEMO87-2
REM
REM     ****NOVRAM ADDRESS LIST****
REM
REM     63520 LED danger condition marker
REM     63521 High engine temp
REM     63522 High engine torque
REM     63523 Power on minutes
REM     63524 Power on hours
REM     63525 Start cycles
REM     63526 Last occuring fault


*************************************************************************

10 GOTO 3320

REM  ****TIME CHECK****

REM Z1 is present time in sec:Z2 is present time in min
REM M is new minutes;S is new seconds

50 GETTIME
55 Z2=PEEK(T+8)*10+PEEK(T+9):Z1=PEEK(T+10)*10+PEEK(T+11)
60 W=0:IF (M<=Z2) AND(S<=Z1) THEN W=1
62 IF M<Z2 THEN W=1
65 RETURN

REM  ****NEW TIME****

REM Subroutine adds the desired time to present time up to the minute
REM S1=sec to be added to present sec S
REM M1=min to be added to present min M

70 GETTIME
75 S=PEEK(T+10)*10+PEEK(T+11)+S1
76 M=PEEK(T+8)*10+PEEK(T+9)+M1
77 IF S>=60 THEN S=S-60:M=M+1
```

```
78 IF M>=60 THEN M=M-60
80 RETURN

REM  ****T.O.T. ALARM ROUTINE****

REM Stores the highest recorded temp(T9) in NOVRAM starting at F820
REM Caution time limits are stored in C9(min) and C8(sec)
REM Voice time is stored in V9(min) and V8(sec)
REM Store time is contained in E2(min) and E1(sec)

95 X1(K)=1:IF R1(K)=3 THEN GOTO 150
96 S2(K)=91:IF R1(K)=1 THEN GOTO 110

REM set up time limits for caution limits and time for voice
97  GOSUB 820:S1=40:M1=4:GOSUB 70:V8(Q1)=S:V9(Q1)=M
98  R1(K)=1:S1=0:M1=5:GOSUB 75:C9(Q1)=M:C8(Q1)=S
100 GOSUB 820

REM check caution time limits
110 S=C8(Q1):M=C9(Q1):GOSUB 50
112 IF W THEN GOTO 150

REM voice chk :voice repeats at 4 min 40 sec of caution limits till danger
124 M=V9(Q1):S=V8(Q1):GOSUB 55
126 IF W THEN GOSUB 820
128 RETURN

REM Entry point to routine if TOT temp between 793 and 843
REM C7(min) and C6(sec) are the caution time limits

130 X1(K)=1:IF R1(K)=3 THEN GOTO 150
131 S2(K)=92:IF R1(K)>=2 THEN GOTO 140

132 OUT 160[1]:OUT 160[50]:GOSUB 820
REM set caution limits
134 R1(K)=2:S1=5:M1=0:GOSUB 70:C7(Q1)=M:C6(Q1)=S
REM set store time limits
136 STORE K,A:M1=0:S1=2:GOSUB 75:E1(Q1)=S:E2(Q1)=M
138 GOSUB 820

REM check time limits
140 M=C7(Q1):S=C6(Q1):GOSUB 50
142 IF W THEN GOTO 150
144 M=E2(Q1):S=E1(Q1):GOSUB 55
146 IF W THEN STORE K,A:S1=2:M1=0:GOSUB 75:E2(Q1)=M:E1(Q1)=S
148 RETURN


REM ****DANGER LIMITS EXCEEDED

150 X1(K)=1:POKE 63526[K]:IF R1(K)=3 THEN GOTO 158
```

```
152 POKE 63520[1]:OUT 160[1]:OUT 160[34]:S2(K)=93:GOSUB 820:R1(K)=3
154 M1=0:S1=1:GOSUB 70
156 E2(Q1)=M:E1(Q1)=S:S1=2:M1=0:GOSUB 75:V9(Q1)=M:V8(Q1)=S

158 S=E1:M=E2:GOSUB 50
160 IF W THEN STORE K,A:S1=1:M1=0:GOSUB 75:E1(Q1)=S:E2(Q1)=M
162 M=V9(Q1):S=V8(Q1):GOSUB 55
164 IF W THEN GOSUB 820:S1=10:M1=0:GOSUB 75:V8(Q1)=S:V9(Q1)=M
166 RETURN



REM ****DIGITAL MESSAGE VOICE ROUTINE****

680 STORE K,X:IF S1(K)<>1 THEN GOTO 740
700 S=S2(K):GOSUB 1340:S=32:GOSUB 1440:DELAY 310:S=S3(K):GOSUB 1460
720 RETURN
740 S=S2(K):GOSUB 1340:S=S3(K):GOSUB 1440
760 RETURN


REM  ****ANALOG MESSAGE VOICE ROUTINE****

REM Routine also stores the channel number and the value in EAROM

820 STORE K,A
830 S=S2(K):GOSUB 1340:S=S3(K):GOSUB 1340:F2=C1(K-31)*A:IF K=33 THEN F2=F2-25
840 GOSUB 3020:S=S4(K):GOSUB 1340:RETURN



REM  ****1st ALARM CONDITION SUBROUTINE****

REM  Caution condition entry point

1000 X1(K)=1:S2(K)=91:POKE 63526[K]:IF R1(K) OR PEEK (63520)THEN GOTO 1020
1005 R1(K)=1:OUT 160[1]:OUT160[50]:IF K>30 THEN GOSUB 820
1007 IF K<31 THEN GOSUB 680
1010 M1=0:S1=2:GOSUB 70
1015 T1(K)=S:T2(K)=M
1020 S=T1(K):M=T2(K):GOSUB 50
1025 IF W AND (K>30) THEN GOSUB 820:S1=30:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1030 IF W AND (K<31) THEN GOSUB 680:S1=30:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1035 RETURN

REM  Warning condition entry point

1156 X1(K)=1:S2(K)=92:POKE 63526[K]:IF R1(K)=2 OR PEEK(63520)THEN GOTO 1164
1157 R1(K)=2: OUT 160[1]:OUT160[50]:IF K>30 THEN GOSUB 820
1158 IF K<31 THEN GOSUB 680
1160 M1=0:S1=2:GOSUB 70
```

```
1162 T1(K)=S:T2(K)=M
1164 S=T1(K):M=T2(K):GOSUB 50
1166 IF W AND (K>30) THEN GOSUB 820:S1=20:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1168 IF W AND (K<31) THEN GOSUB 680:S1=20:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1169 RETURN

REM  Danger condition entry point

1170 X1(K)=1:S2(K)=93:POKE 63526[K]:IF R1(K)=3  THEN GOTO 1180
1172 R1(K)=3:OUT 160[1]:OUT160[34]:IF K>30 THEN GOSUB 820
1173 IF K<31 THEN GOSUB 680
1174 M1=0:S1=2:GOSUB 70
1176 T1(K)=S:T2(K)=M
1180 S=T1(K):M=T2(K):GOSUB 50
1182 IF W AND (K>30) THEN GOSUB 820:S1=10:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1184 IF W AND (K<31) THEN GOSUB 680:S1=10:M1=0:GOSUB 75:T1(K)=S:T2(K)=M
1200 RETURN


REM  ****SPEECH SYNTH****

REM  1st speech PROM

1340 IF INP(A1)<>1 THEN GOTO 1340
1360 OUT 112[S]
1380 A1=116
1400 RETURN

REM 2nd speech PROM

1440 IF INP(A1)<>1 THEN GOTO 1440
1460 OUT 113[S]
1480 A1=117
1500 RETURN


REM  ****ANALOG CHANNEL INPUT ROUTINE****

1540 OUT P[0]
1560 IF INP(16)=0 THEN GOTO 1560
1580 A=INP(P)
1640 RETURN



REM  ****INTERUPT CONTROL SUBROUTINES****

1700 PUSH X,Y,I,K,S,Z2,Z1
1720 X=255-INP(64):POKE 63520[1]:IF X=0 THEN GOTO 2200
1730 Y=1:POKE 63520[1]
1734 FOR K=2 TO 4
1735 IF X AND Y THEN GOSUB 1170:GOTO 1750
```

```
1750 Y=2*Y
1760 NEXT
1780 GOTO 2200

1800 PUSH X,Y,I,K,S,Z2,Z1
1820 X=255-INP(65):IF X=0 THEN GOTO 2200
1840 Y=1
1860 FOR K=8 TO 11
1880 IF X AND Y THEN GOSUB 1156:GOTO 1900
1900 Y=2*Y
1920 NEXT
1940 GOTO 2200

1960 PUSH X,Y,I,K,S,Z2,Z1
1980 X=255-INP(80): IF X=0 THEN GOTO 2200
2000 Y=1
2020 FOR K=16 TO 22
2040 IF X AND Y THEN GOSUB 1000:GOTO 2060
2060 Y=2*Y
2080 NEXT
2100 GOTO 2200

2120 PUSH X,Y,I,K,S,Z2,Z1
2140 X=255-INP(81): IF X=0 THEN GOTO 2200
2160 IF X AND 1 THEN K=24:GOSUB 1000:GOTO 2180
2180 IF X AND 2 THEN K=25:GOSUB 1000:GOTO 2200

2200 Z1=POP(1):Z2=POP(1):S=POP(1):K=POP(1)
2220 I=POP(1):Y=POP(1):X=POP(1)
2240 RETI


REM  ****TIME CHECK SUBROUTINE****

2300 S=39: GOSUB 1340
2320 GETTIME: FO=53: H=PEEK(T+6)*10+PEEK(T+7)
2340 IF H>11 THEN FO=71: H=H-12
2360 IF H=0 THEN H=12
2380 S=H: GOSUB 1340
2400 M1=PEEK(T+8): M2=PEEK(T+9)
2420 IF M1>1 THEN S=M1+18: GOSUB 1340: GOTO 2460
2440 IF M1=1 THEN M2=M2+10
2460 IF M2<>0 THEN S=M2: GOSUB 1340
2480 S=FO: GOSUB 1340
2500 RETURN


REM  ****SYSTEM CHECK SUBROUTINE****

REM do voltage channels

2580 S=40: GOSUB 1340
```

```
2600 FOR I=1 TO 5
2620 P=I+7:K=I+31
2640 OUT P[0]: DELAY 100: V(P)=INP(P)
2660 F2=INP(P)*C1(I)
2680 IF I=2 THEN F2=F2-25
2700 S=S3(K):GOSUB 1340:GOSUB 3020:S=S4(K):GOSUB 1340
2720 NEXT
2740 RETURN

REM  do frequency channels

2780 K=P1+37
2800 OUT P1[0]
2820 Y1=0: Y=INP(4)
2840 Y=INP(7): Y1=Y1+1
2860 IF Y1>9 THEN F2=0:GOTO 2960
2880 IF Y=254 THEN GOTO 2840
2900 IF Y=253 OR Y=255 THEN F2=0:GOTO 2960
2920 F1=1.2288E+06/(INP(5)+INP(6)*256)
2940 F2=INT(F1*60/42.12)
2960 A=F2:RETURN



REM  ****UNIT TO SPEECH CONVERSION****

3020 A9=INT(F2/100): F3=F2-A9*100: B=INT(F3/10): C=INT(F3-B*10)
3040 IF A9<>0 THEN S=A9: GOSUB 1340: S=28: GOSUB 1340
3060 IF B=1 THEN C=C+10: GOTO 3100
3080 IF B<>0 THEN S=B+18: GOSUB 1340
3100 IF C<>0 THEN S=C: GOSUB 1340
3120 IF A9=A9 AND B=0 AND C=0 THEN S=0: GOSUB 1340
3140 RETURN



REM ***************** MAIN PROGRAM *********************

REM  ****SET UP DIGITAL MESSAGE TABLE****

REM  S1(K) indicates whether or not word needs to be spliced
REM  S2(K) is the status of message word i.e. "caution ...
REM  S3(K) is the 2nd word of the message
REM  S4(K) is then 4th word of analog messages

3320 DIM S1(40),S2(40),S3(40),S4(40),V(16),R1(40),T1(40),T2(40),X1(40)
3340 FOR I=0 TO 32
3360 S3(I)=I
3380 NEXT

REM set word splice flag for "transmission"
```

```
3420 S1(4)=1:S1(20)=1:S1(21)=1

REM  set status vord
REM  91= caution, 92= warning, 93=danger

3460 S2(2)=93:S2(3)=93:S2(4)=93:S2(24)=91:S2(25)=91
3480 FOR I=8 TO 11
3500 S2(I)=92
3520 NEXT
3540 FOR I=16 TO 22
3560 S2(I)=91
3580 NEXT

REM   ************************************


REM   ****SET UP ANALOG MESSAGE TABLE****

3640 FOR I=1 TO 8
3660 K=I+82:J=I+31:S3(J)=K
3680 NEXT
3700 S4(32)=57:S4(33)=57:S4(34)=70:S4(35)=62:S4(36)=72:S4(37)=70:S4(38)=70
3720 S4(39)=70

REM  Set up constants for conversion

REM Torque constant C1(3) is set for the allison chambers 250C20 engine
REM C1(1)=TOT,C1(2)=ambient temp,C1(4)=fuel level,C1(5)=fuel pressure
REM C1(6,7,8) are the tachgenerator constants

3780 C1(1)=3.96078:C1(2)=.2852:C1(3)=.51262:C1(4)=.294118:C1(5)=.117647
3785 C1(6)=1:C1(7)=1:C1(8)=1

REM     ************************************


REM  Initialize time on hours T4

3820 PRINT "DEMO87 RUNNING...":PRINT
3840 OUT 120[15,7], 124[79,7] 3860 OUT 66[0,255,255,23,0], 67[2,255,255,23,0]
3880 OUT 82[4,255,255,23,0], 83[6,255,255,23,0]
3882 A=63520:IF PEEK(A) THEN OUT 160[1]:OUT 160[34]:GOTO 3920
3900 OUT 160[1]: DELAY 10: OUT 160[18]
3920 A1=116

3930 S=94:GOSUB 1340:DELAY 1000
4060 T=8192: GOSUB 2300: O=PEEK(T+8)

REM  initialize time on hours T4
4061 T4=PEEK(T+8)*10+PEEK(T+9)

REM  **Check T.O.T. status**
```

```
4120 Q1=1:P=8: K=32:GOSUB 1540
4122 IF A>T9 THEN T9=A:POKE 63521[A]
4140 IF (A>187) AND (A<199) THEN GOSUB 95:GOTO 4220
4160 IF (A>=199)AND (A<212) THEN GOSUB 130:GOTO 4220
4180 IF A>=212 THEN GOSUB 150:GOTO 4220
4182 R1(32)=0

REM  *******

4220 INTON 0,1700:INTON 1,1800:INTON 2,1960:INTON 3,2120: OUT 96[0]
4230 OUT 66[131]

REM  **Check Torque status**

4260 Q1=2:P=10: K=34:GOSUB 1540
4265 IF A>T8 THEN T8=A:POKE 63522[A]
4280 IF (A>165) AND (A<195) THEN GOSUB 95:GOTO 4360
4300 IF (A>=195) AND (A<214) THEN GOSUB 130:GOTO 4360
4320 IF (A>=214) THEN GOSUB 150:GOTO 4360
4330 R1(33)=0

REM  ********

4360 OUT 67[131]

REM  **Check Tachometer status**

4400 P1=0:K=37:GOSUB 2780:IF (Z5=0) AND (F2<60) THEN GOTO 4620
4405 IF (Z5=0) AND (F2>=60) THEN Z5=1:Q=PEEK(63525)+1:POKE 63525[Q]:GOTO 4620
4420 IF F2<60 THEN GOSUB 1156:GOTO 4460
4440 IF F2>104 THEN GOSUB 1170:GOTO 4460
4450 R1(37)=0
4460 P1=1:K=38:GOSUB 2780
4480 IF F2<95 THEN GOSUB 1152:GOTO 4520
4500 IF F2>100 THEN GOSUB 1170:GOTO 4520
4510 R1(38)=0
4520 P1=2:K=39:GOSUB 2780
4540 IF F2<90 THEN GOSUB 1152:GOTO 4620
4560 IF F2>107 THEN GOSUB 1170:GOTO 4620
4510 R1(38)=0

REM  *********

REM  **Check CH-70 switches for caution suppression**

4620 OUT 160[2]: DELAY 5: Q=INP(160)
4640 IF Q AND 128 THEN OUT 82[131]

REM  *********

REM  **Check fuel quantity**
```

```
4720 P=11:K=35:GOSUB 1540
4740 IF A <17 THEN GOSUB 1170:GOTO 4840
4760 IF (A >=17) AND (A<34) THEN GOSUB 1156:GOTO 4840
4780 IF (A>=34) AND (A<68) THEN GOSUB 1000:GOTO 4840
4790 R1(35)=0
REM  ********

REM  **Check fuel pressure**

4840 P=12:K=36:GOSUB 1540
4860 IF A<35 THEN GOSUB 1156:GOTO 4920
4880 IF A=255 THEN GOSUB 1170:GOTO 4920
4890 R1(36)=0

REM  ****Check CH-70 for caution suppression****

4920 OUT 160[2]: DELAY 10: Q=INP(160)
4940 IF Q AND 128 THEN OUT 83[131]

REM  *******


5000 REM **Check CH-70 for system check switch**
5020 OUT 160[2]: DELAY 10: Q=INP(160)
5040 IF Q AND 64 THEN GOTO 5180
5060 GOSUB 2580
5080 FOR P1=0 TO 2
5100 GOSUB 2780
5120 S=S3(K):GOSUB 1340:GOSUB 3020:S=S4(K):GOSUB 1340
5140 NEXT

REM  **Time and temperature check**

5180 GETTIME: M=PEEK(T+8): IF M=0 THEN GOTO 5265
5220 O=M:GOSUB 2300
5240 K=33:P=9:GOSUB 1540:F2=A*C1(2)-25
5260 S=84:GOSUB 1340:GOSUB 3020:S=57:GOSUB 1340

REM find pover on hours
REM hours are stored in NOVRAM at 63524
REM minutes are stored in NOVRAM at 63523

5265 T3=PEEK(T+8)*10+PEEK(T+9):T6=PEEK(63524)
5266 IF T4=T3 THEN GOTO 5275
5267 T5=T3-T4:T4=T3:IF T5<0 THEN T5=T5+60
5269 T5=T5+PEEK(63523)
5271 IF T5>=60 THEN T5=T5-60:T6=T6+1:POKE 63524[T6]
5273 POKE 63523[T5]
REM  Turn off LED if no cautions
5274 L2=0
5275 FOR I=1 TO 39
```

```
5276 IF X1(I) THEN L2=1:GOTO 5280
5278 R1(I)=0
5280 X1(I)=0
5282 NEXT

5299 A=63520:IF L2 OR PEEK(A) THEN GOTO  5320
REM  Turn LED green if no alarm condition
5300 OUT 160[1]:DELAY 5:OUT 160[18]
5320 L2=0

REM  ****MESSAGE TABLE READOUT****

REM  ****Check for dump****

5420 INTOFF
5500 OUT 160[2]:DELAY10:Q=INP(160)

5510 IF Q AND 32 THEN GOTO 6000
5520 DUMP
5522 PRINT"Last fault:  ",PEEK(63526)
5525 PRINT"Highest engine temp:  ",PEEK (63521)*C1(1),"degrees C"
5530 PRINT"Highest engine torque:  ",PEEK(63522)*C1(3),"PSI"
5540 PRINT"Power on hours=",PEEK(63524),"hours/",PEEK(63523),"minutes"
5550 PRINT"Number of start cycles  :",PEEK(63525)
6000 GOTO 4120
REM*************************************************************************

10000 INPUT "CLEAR POWER ON HOURS   ";S
10010 IF S THEN POKE 63523[0]:POKE 63524[0]
10020 POKE 63520[0]
10030 POKE 63521[0]
10040 POKE 63522[0]
10050 INPUT"CLEAR START CYCLES";S
10060 IF S THEN POKE 63525[0]
```